JOURNAL OF THE IRON AND STEEL INSTITUTE

JUNE 1961
Volume 198 Part 2

Established 1869
Incorporated by Royal Charter 1899

Presidential address: Steel in an expanding Britain
Sir Charles Goodeve 117

Review: 'The determination of gases in metals'
C. J. Smithells 124

Reconstitution of the light section mill at Round Oak
W. S. Walker et al. 126

Vacuum steelmaking
A. M. Samarin 131

Examination of oxide scales on Fe–Cr alloys by X-ray scanning microanalysis
G. C. Wood and D. A. Melford 142

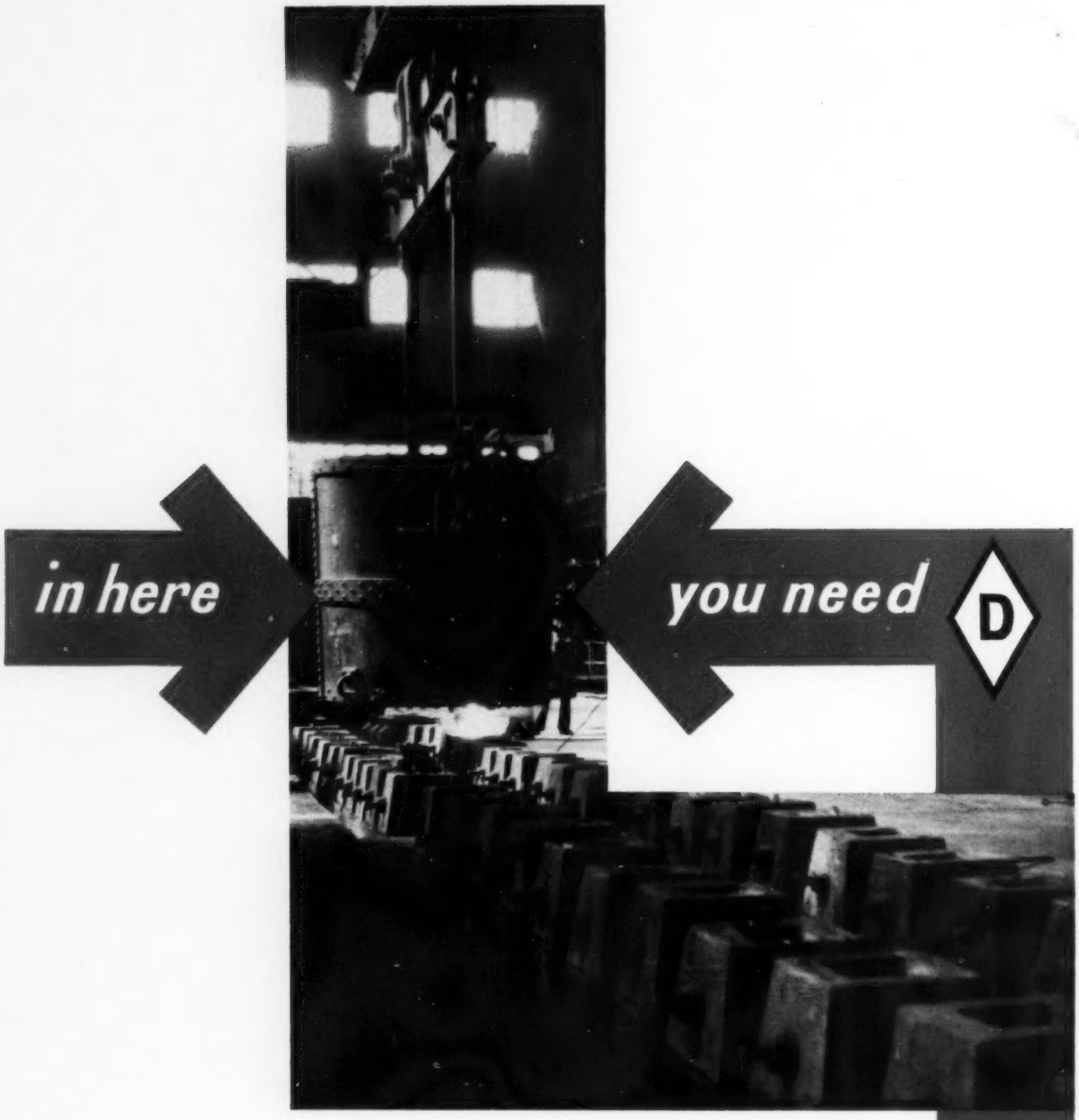
English bloomeries (1329–1589)
R. A. Mott 149

An effect of composition on the macrostructure of ingots of a low-alloy steel
T. B. Smith et al. 161

Discussion at Autumn General Meeting, 1960, on martensite 165

News 181 Abstracts 185

A full list of contents is given on the Title Page (see page 53 of the Advertisement Section)



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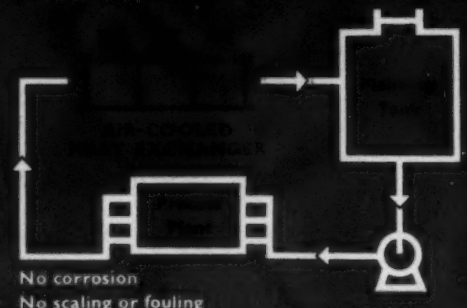

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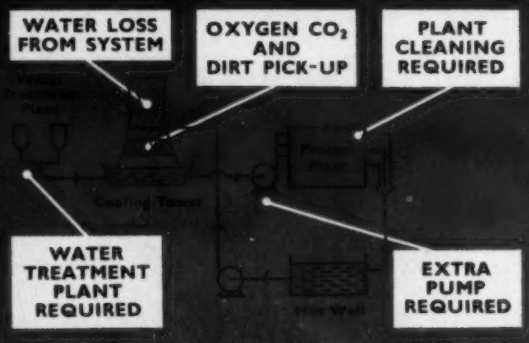

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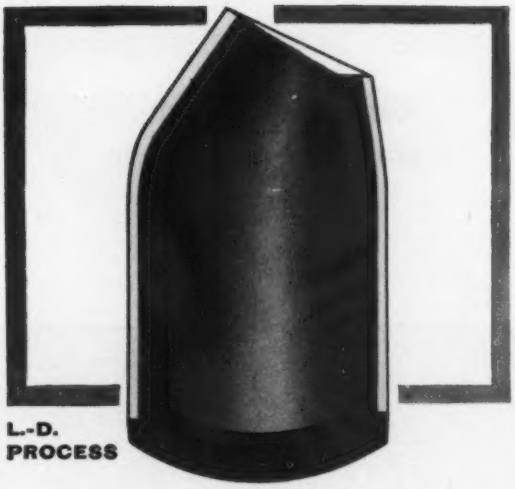

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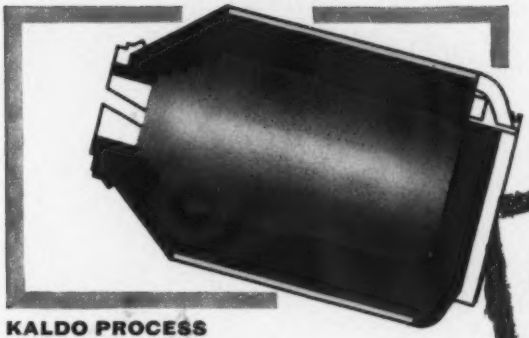

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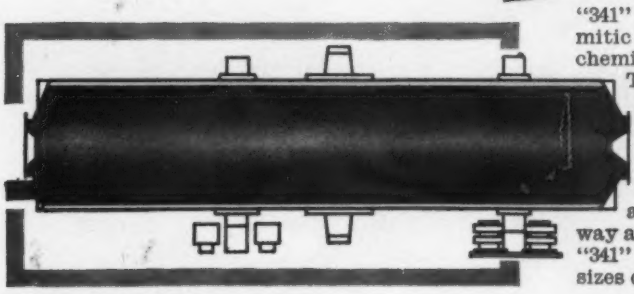

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2/3%	0.2%	1/2%	0.1%	1/2%	48/50%	36/40%

Typical Physical Properties

TRUE POROSITY %	18/20
BULK DENSITY grams per c.c.	2.70/2.75
SPECIFIC GRAVITY	3.35
SPECIFIC HEAT	0.25
PERMEABILITY c.g.s units	0.05
COLD CRUSHING STRENGTH p.s.i.	+8,500
Kilos sq.cm.	+ 600
SPALLING INDEX (small prism test)	Cycles +30
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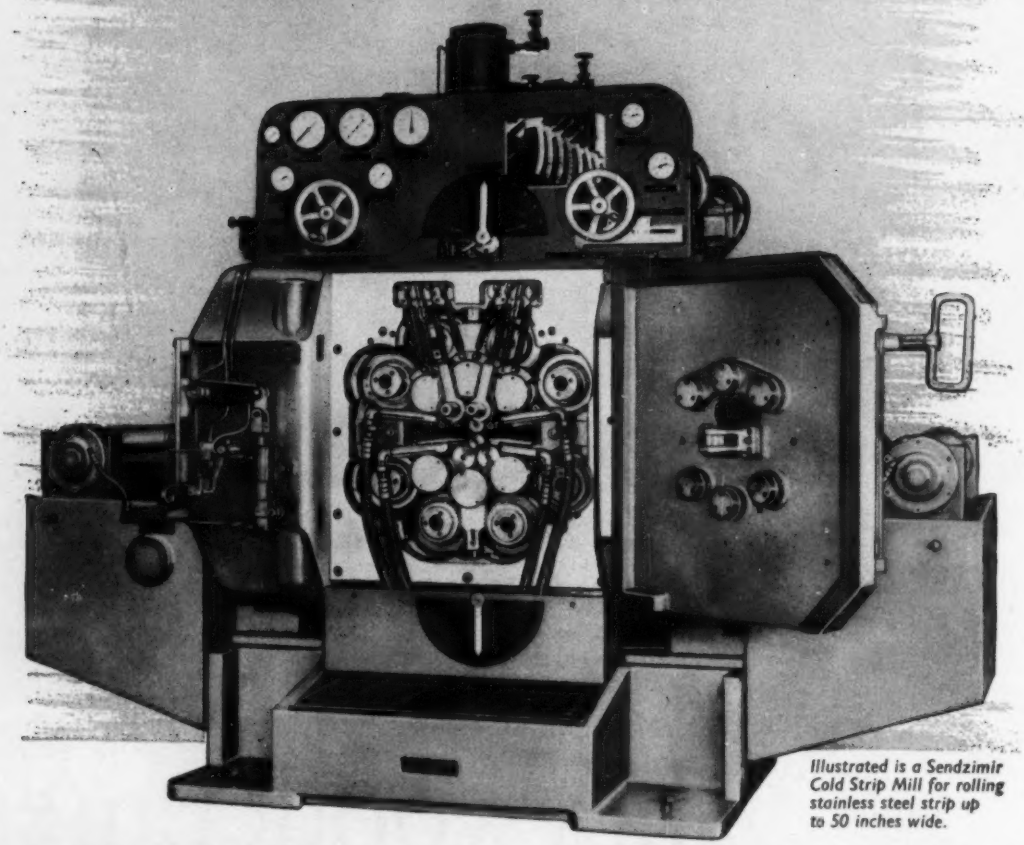

Illustrated is a Sendzimir Cold Strip Mill for rolling stainless steel strip up to 50 inches wide.

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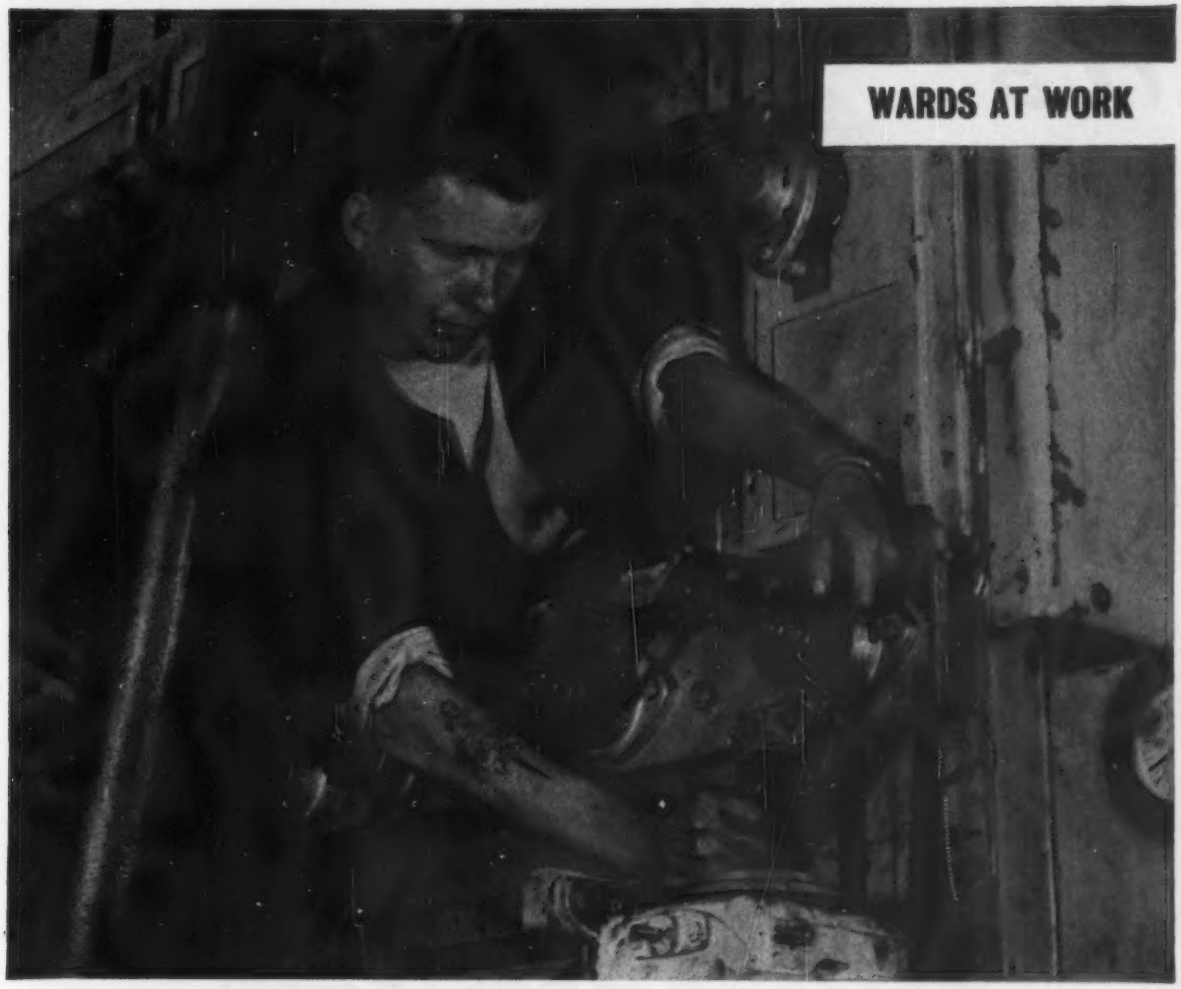

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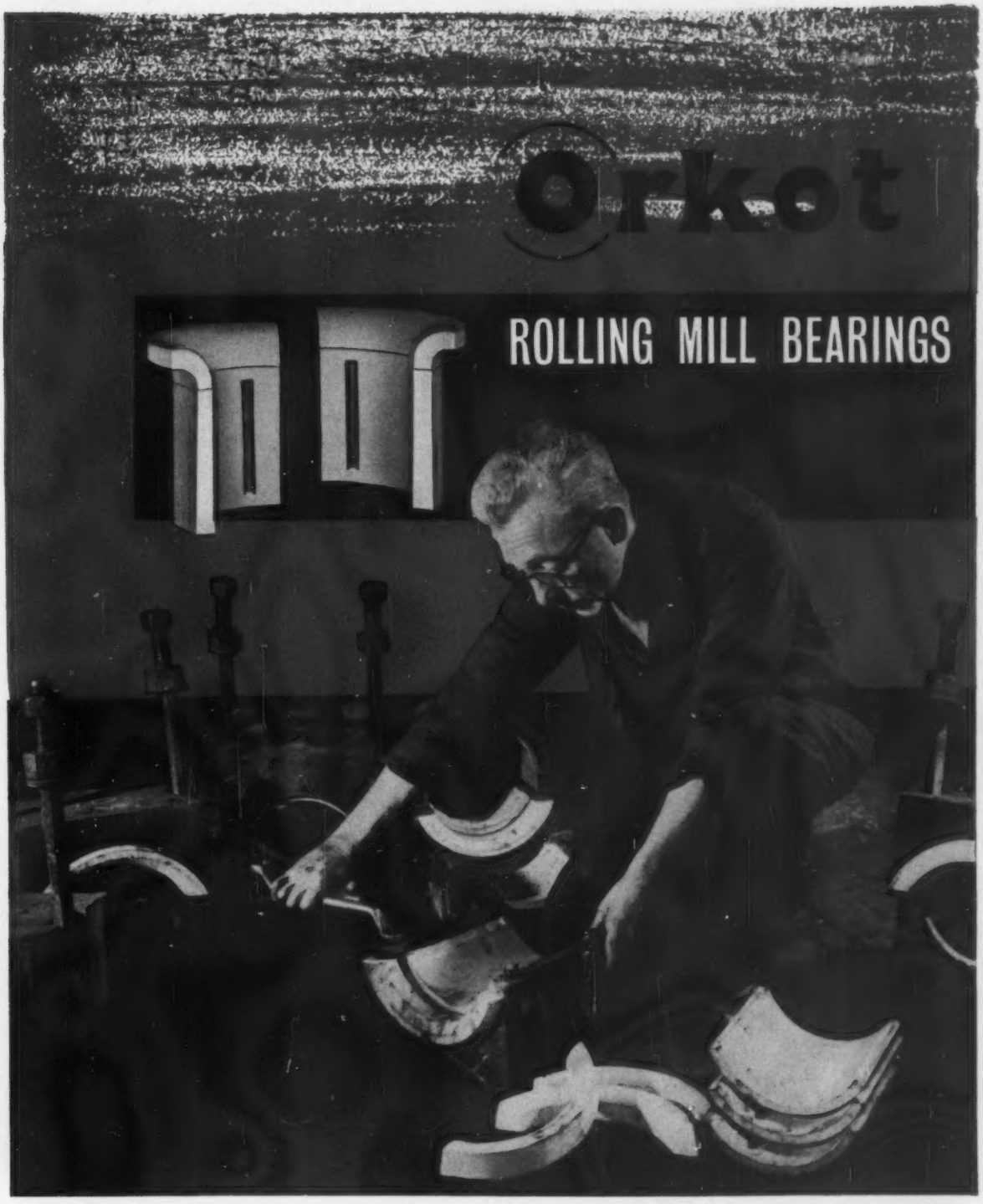

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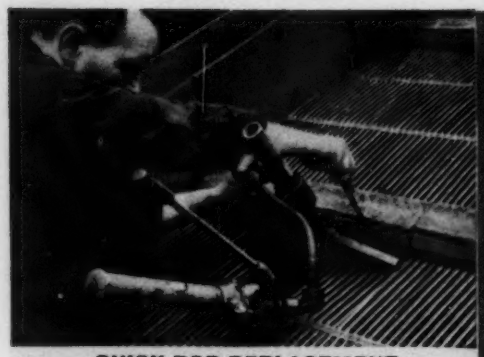

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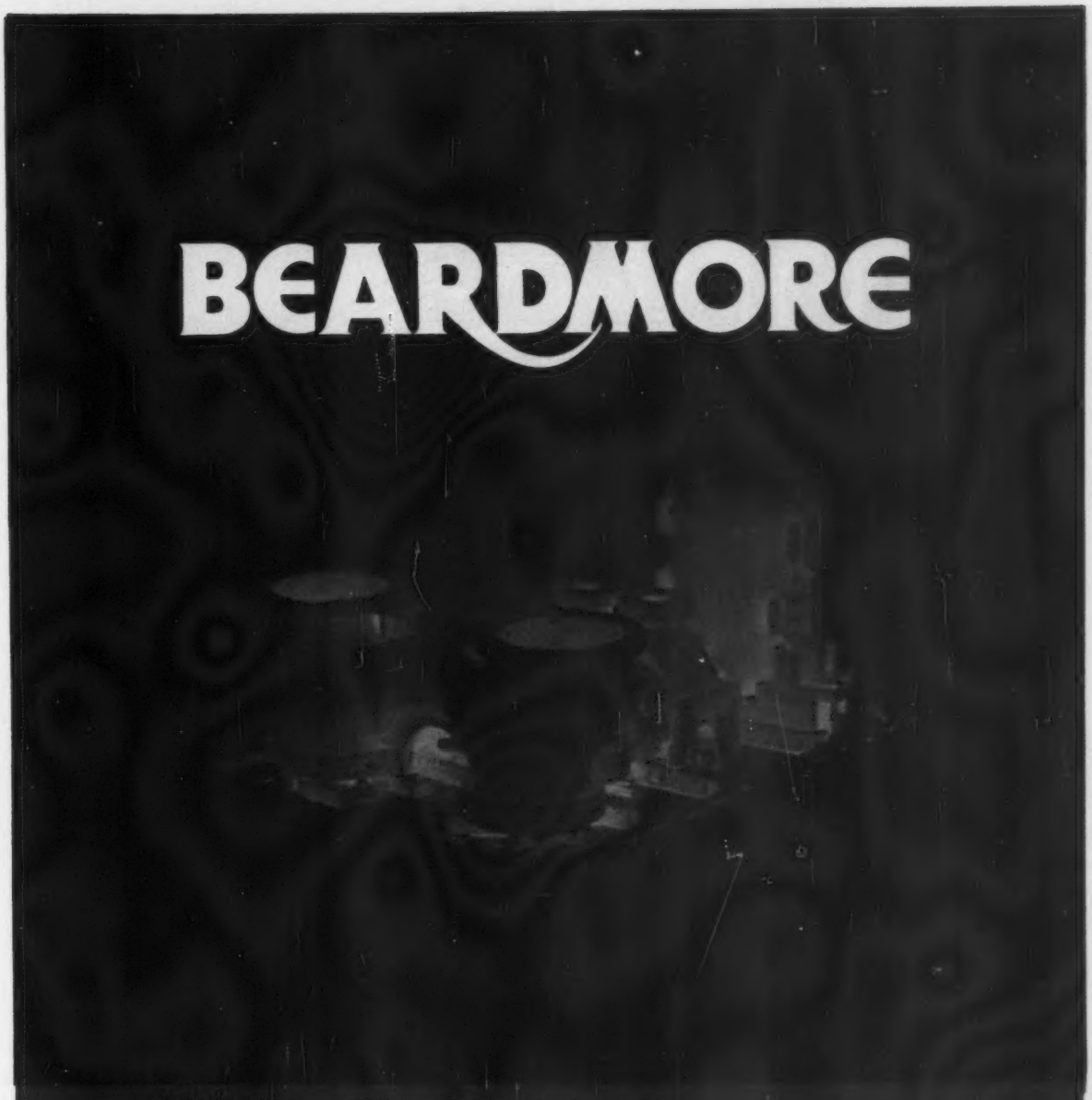

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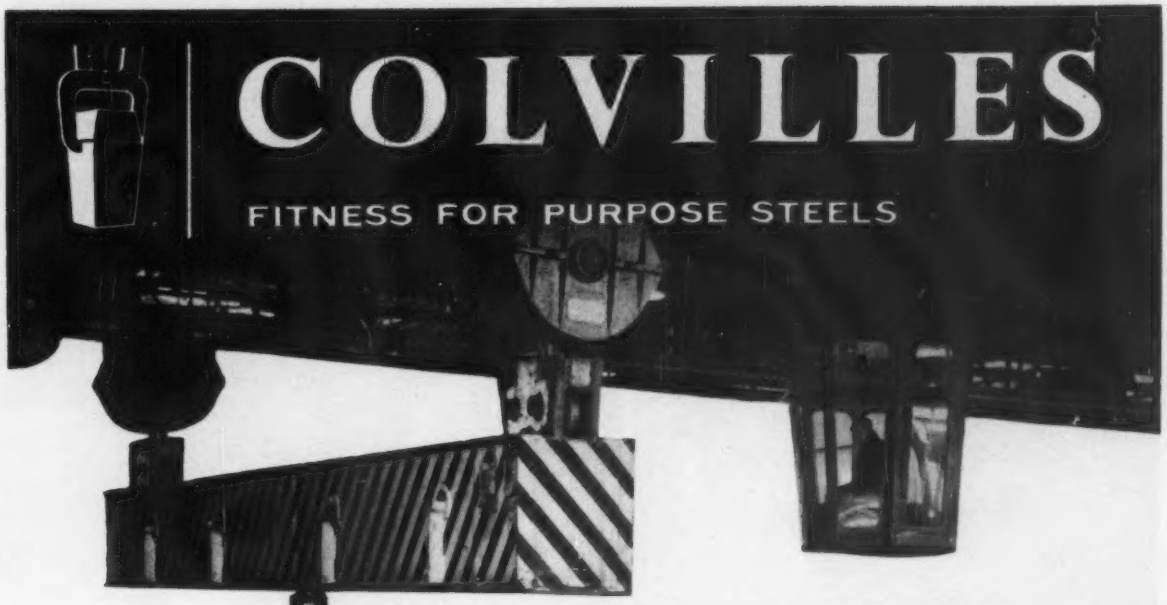

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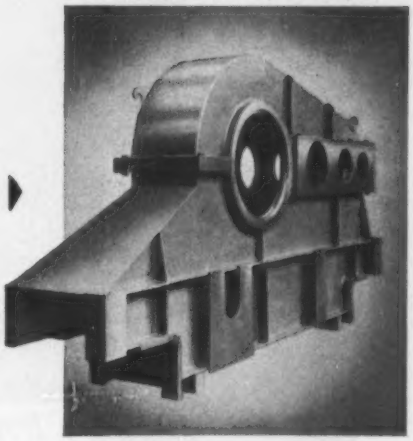
Craneage for the Steel Industry

Upper photograph by courtesy of Messrs. Thomas Firth & John Brown Ltd.

A 130/40 tons heavy duty electric overhead travelling crane handling forgings in the Bessemer Heat Treatment Department at Messrs. Thos. Firth & John Brown Ltd., Sheffield.



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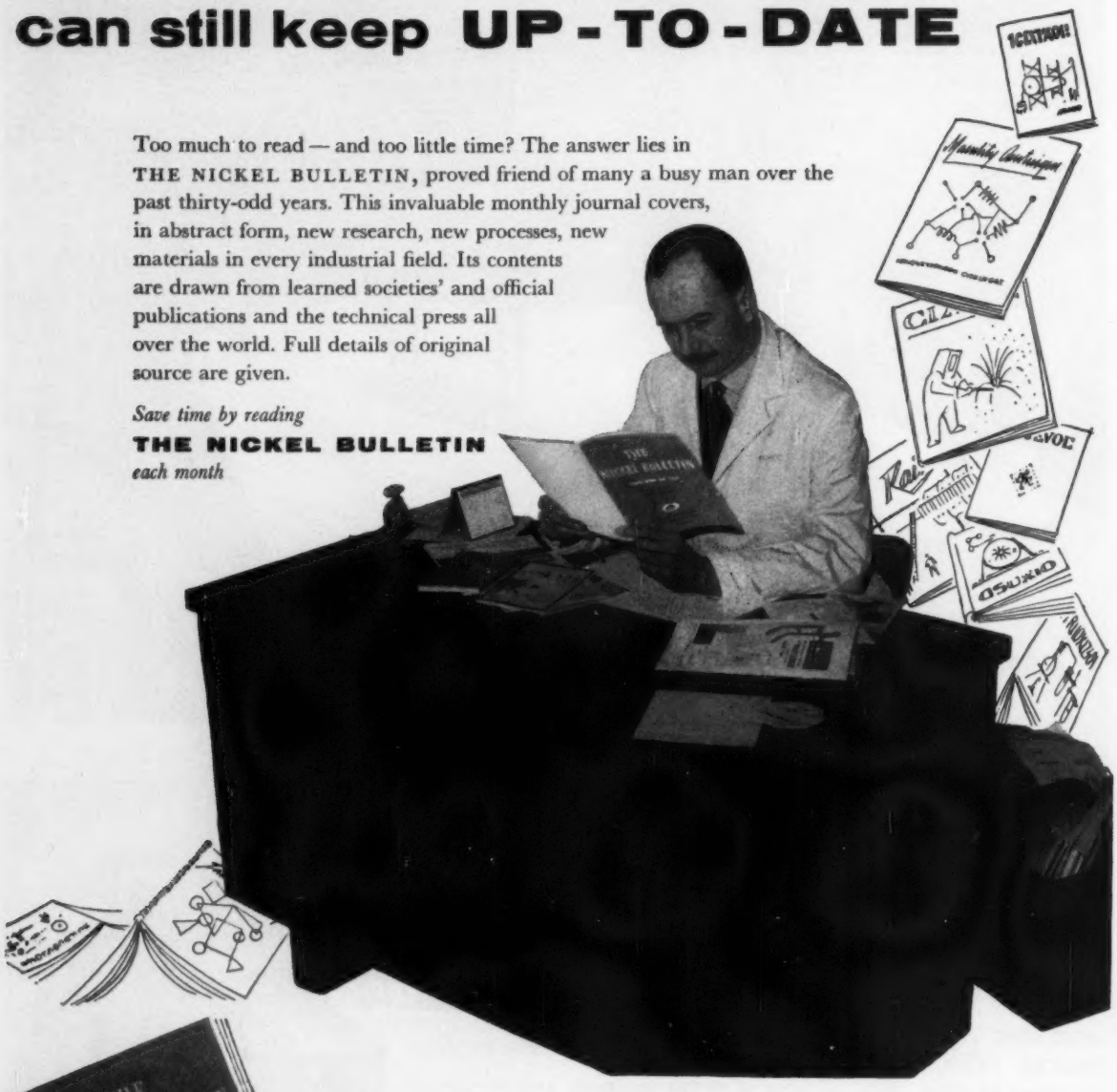

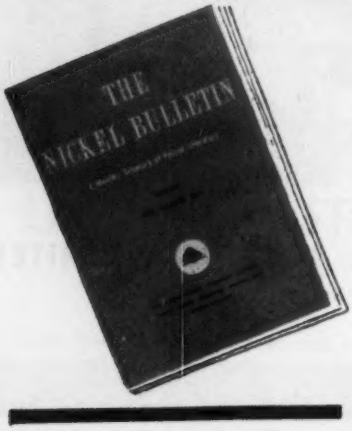

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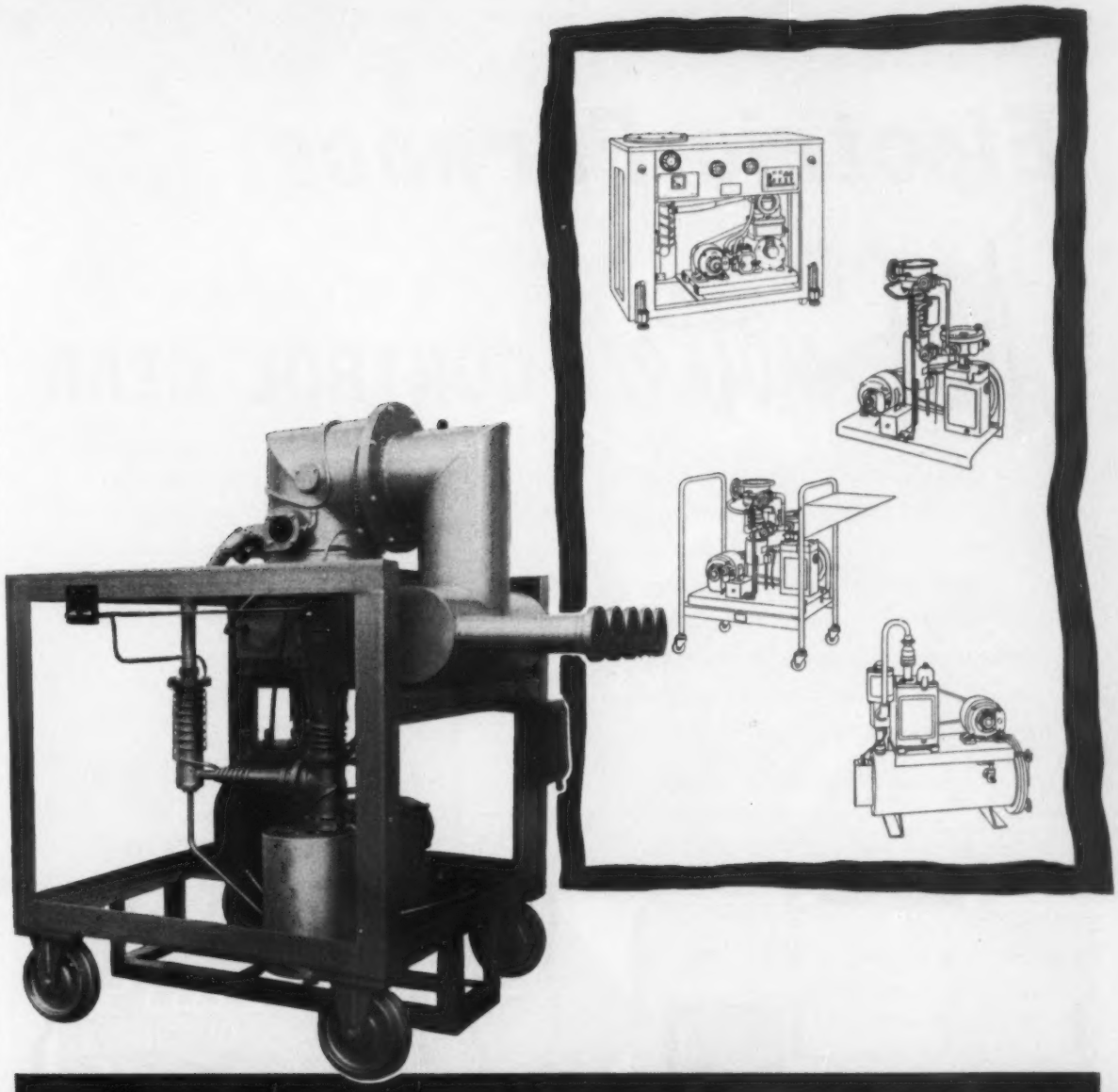

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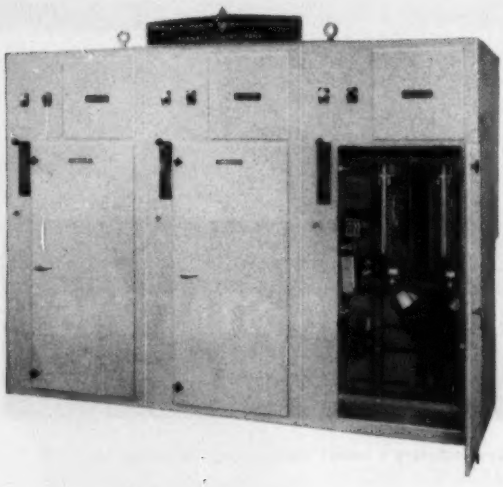

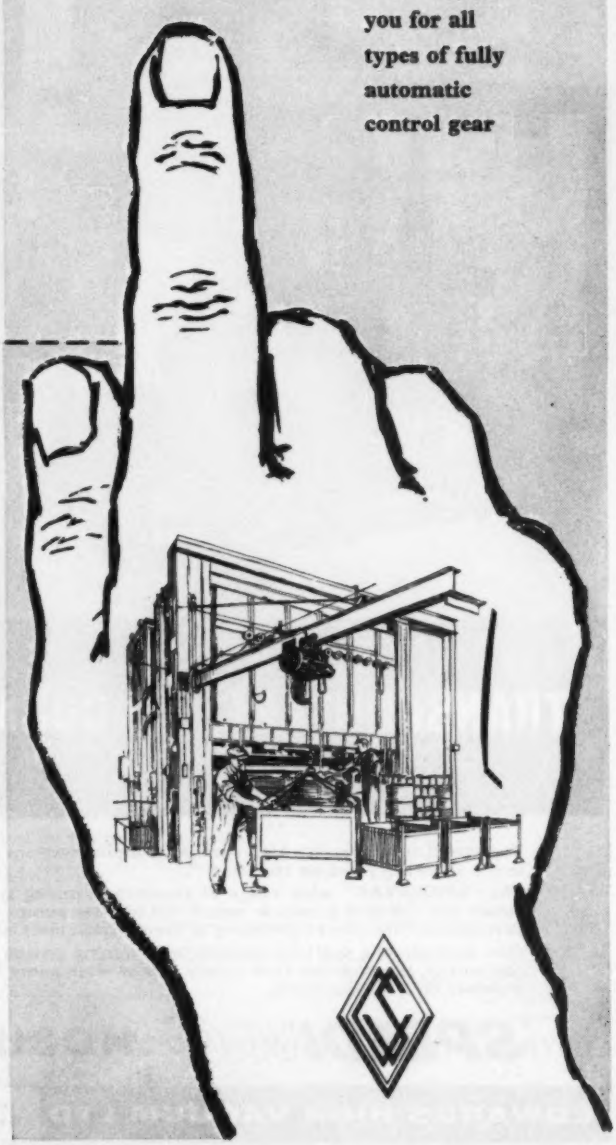

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PARSONS turbo-blowers & turbo-generators

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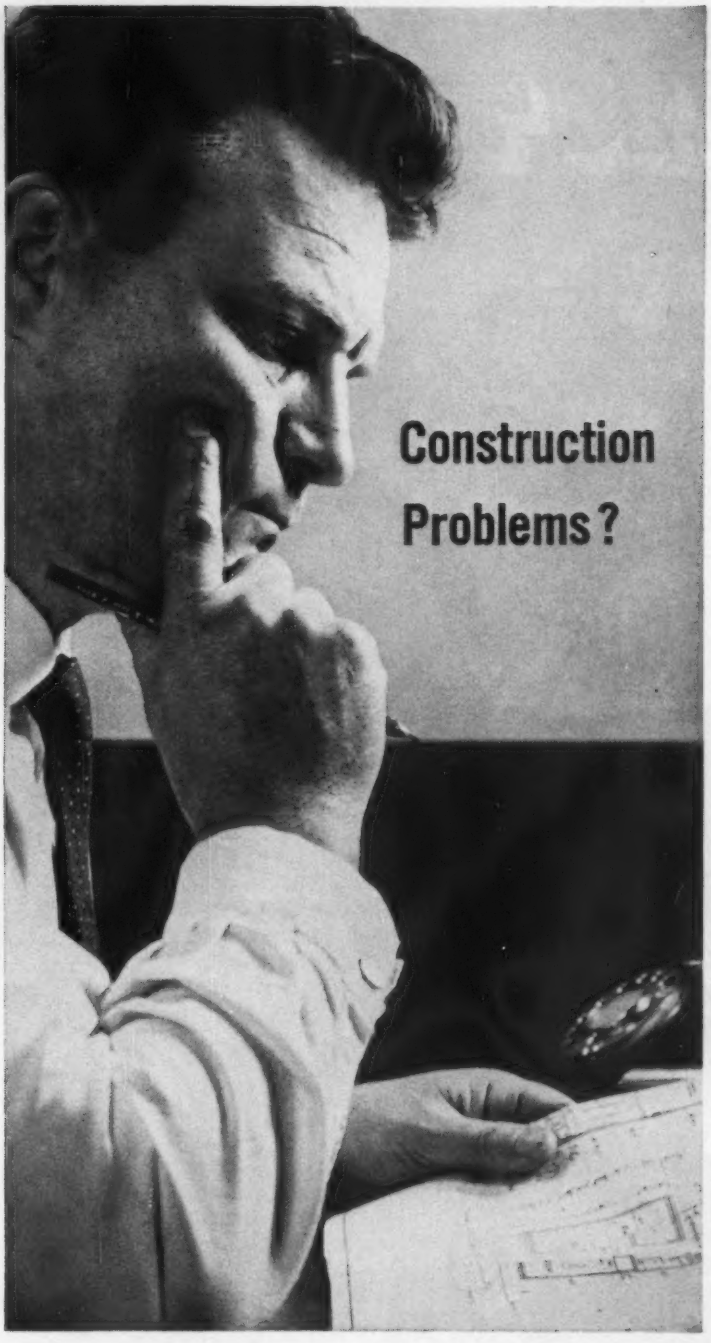
HEATON WORKS · NEWCASTLE UPON TYNE · 6



William Press and Son Limited are carrying out major contracts in Civil Engineering, Pipeline Construction, Industrial Pipework Fabrication and Plant Erection. Its subsidiaries offer a wide range of ancillary services, including the cleaning and reconditioning of every type of pipeline; the manufacture of specialised equipment for the maintenance of pipelines; cathodic protection; welding inspection; central heating; ventilating; steam and hot water services for industrial and domestic purposes.

With its fourteen depots throughout the country, high mobility and trained teams of plant operators, The William Press Group offers unrivalled service, speed and efficiency.

PRESS ESTABLISHED 1913

Get in touch with WILLIAM **PRESS**
and Son Limited

22, Queen Anne's Gate, London, S.W.1.
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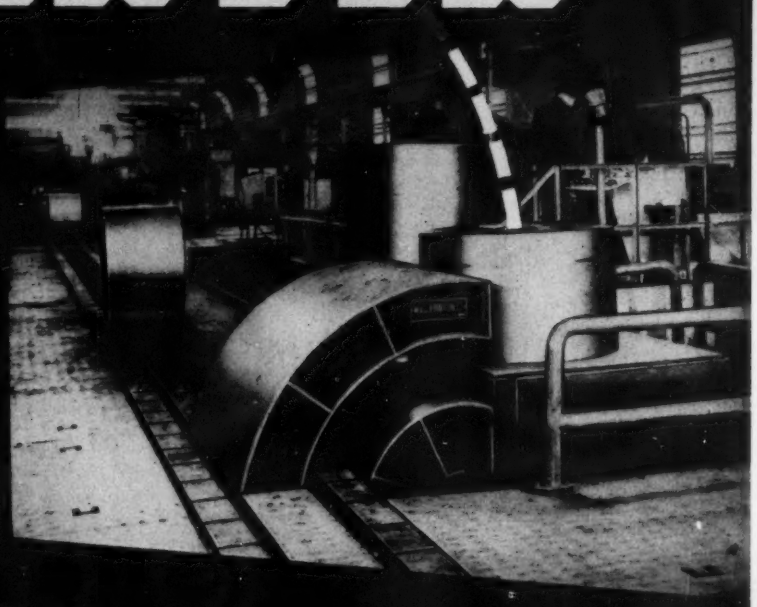
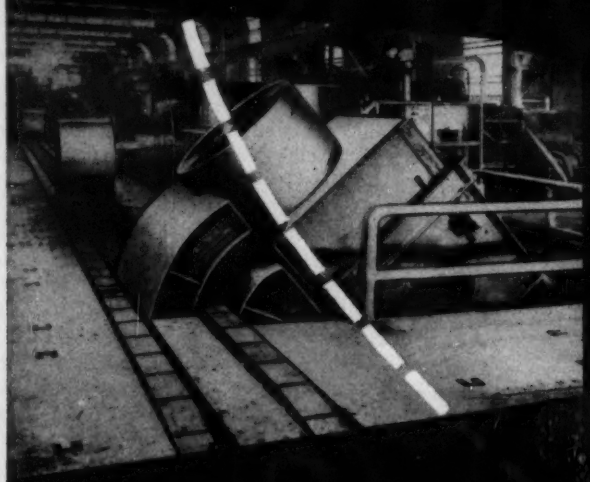
PANTIN

heavy–duty handling systems



Pantin design and manufacture heavy duty mechanical handling plant for the Iron and Steel Industry.

This 'Upender', for example, was made to simplify and expedite the handling of coiled steel. With the utmost ease it takes coils up to 15 tons (max. dimensions 6' diam. × 6' wide) and lays them on a Pantin Pallet Conveyor for movement to the next station.

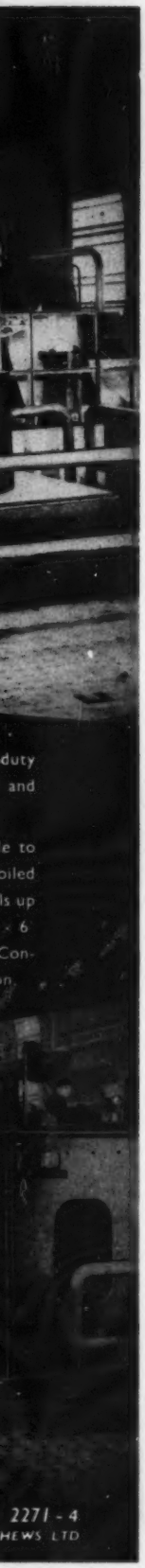


Pantin Handling Equipment covers every requirement, including upending and downending, tilting, hoisting and conveying of coils and sheets.

We are always pleased to discuss, advise and co-operate on the design of handling systems and shall be glad to send you details of Pantin Conveyors and Handling Equipment. Please write for illustrated brochure.

W & C PANTIN LTD CENTRE DRIVE EPPING ESSEX *Telephone EPPING 2271 - 4*

ASSOCIATED COMPANY THE BRITISH MATHEWS LTD



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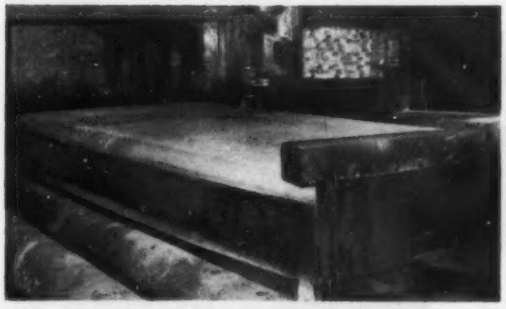
2271 - 4
HEWS LTD

STEEL INSTITUTE

STRENGTH

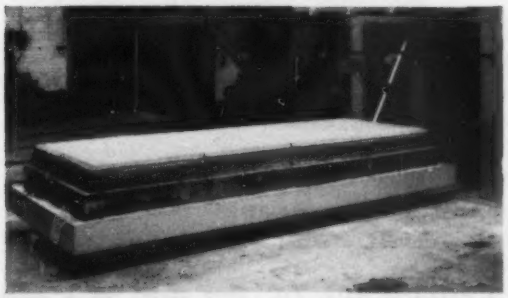
Preheater Furnace Bogies with Plicasto Tuff-Mix linings at the Clydebridge Works of MESSRS. COLVILLES LTD.

SHOCK AND ABRASION RESISTANCE



Bogie hearth lined with Plicasto Tuff-Mix at the DARLINGTON FORGE LTD.

SERVICE



Monolithic Bogie hearths: Birlec elevator furnaces at SIMPLEX ELECTRIC CO. LTD. lined with Plicasto Super Castable Refractory. The first of these hearths had a total life of four years. No failure of materials occurred.

GOOD REASONS WHY YOU TOO SHOULD USE

PLIBRICO

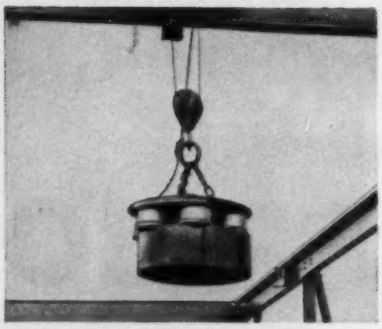
MONOLITHIC REFRACTORIES FOR YOUR BOGIE HEARTH EQUIPMENT

As you can see more and more progressive companies are putting PLIBRICO Monolithic Refractory installations into service and benefiting from the ease and flexibility of installation, efficiency of insulation and length of service with minimal repairs which Plibrico materials and engineering give.

Write or telephone and we will arrange for an Engineer Representative to discuss your refractory problem with you.

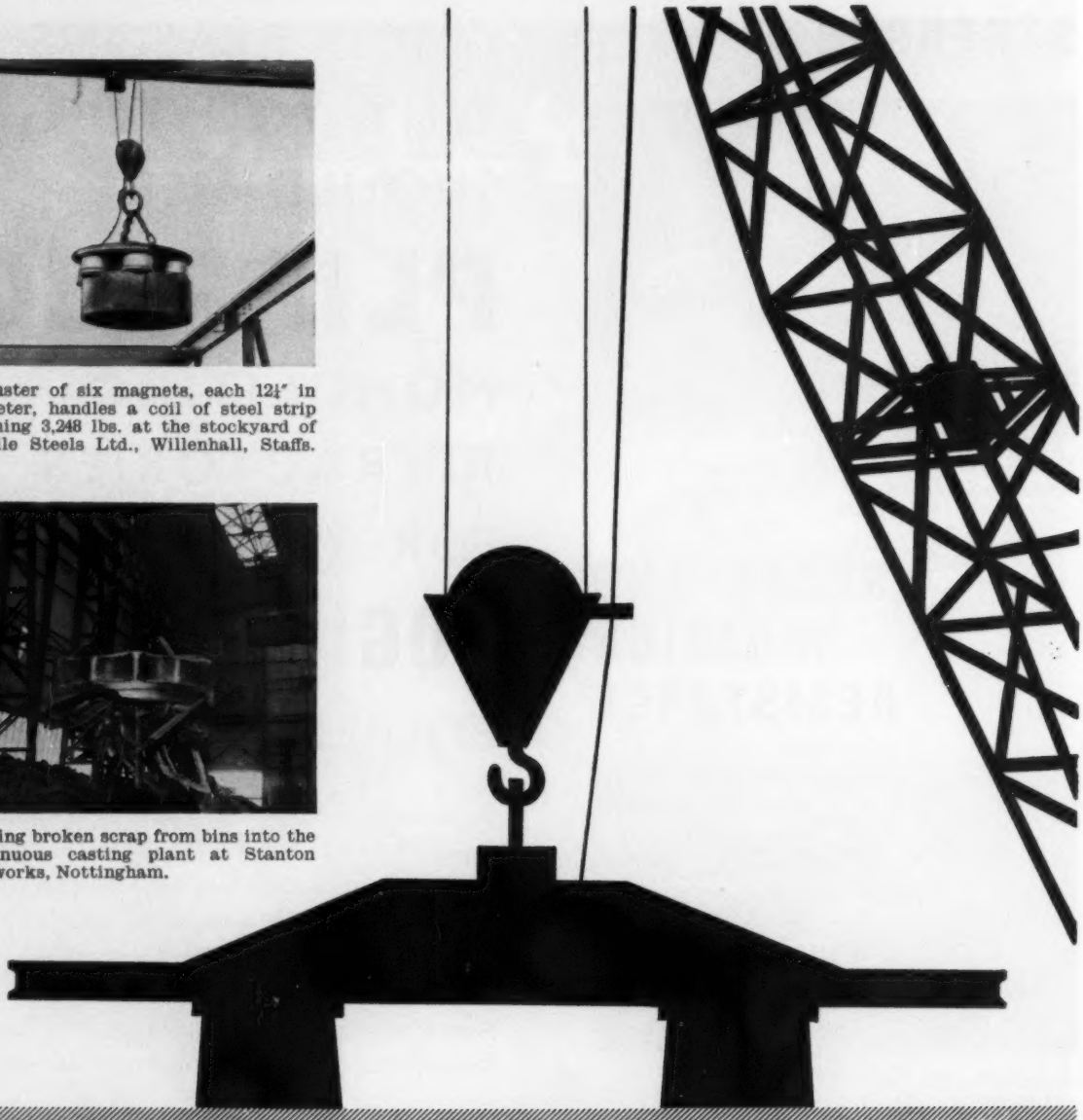
PLIBRICO
COMPANY LIMITED
REFRACTORY ENGINEERS
WESTMORLAND ROAD,
LONDON, N.W.9

Telephone: COLINDALE 8001/6
Telegrams: PLIBRICO HYDE, LONDON

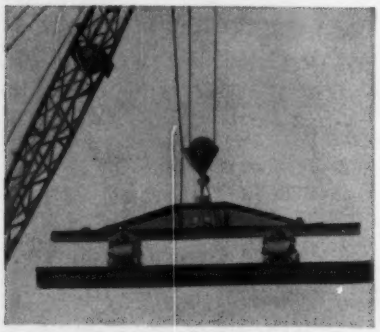


A cluster of six magnets, each 12¼" in diameter, handles a coil of steel strip weighing 3,248 lbs. at the stockyard of Ductile Steels Ltd., Willenhall, Staffs.

Loading broken scrap from bins into the continuous casting plant at Stanton Ironworks, Nottingham.



WITTON-KRAMER LIFTING MAGNETS FOR EVERY JOB



Two bi-polar magnets on spreader beam lifting rolled steel joist.

Whether handling hot steel billets and ingots or salvaging metal from under water, Witton-Kramer electric magnets do the job superbly. Circular, rectangular or bi-polar, G.E.C. makes them all with coils designed and constructed to withstand heavy duty and shock loads. All Witton-Kramer magnets are easily maintained and quickly serviced.

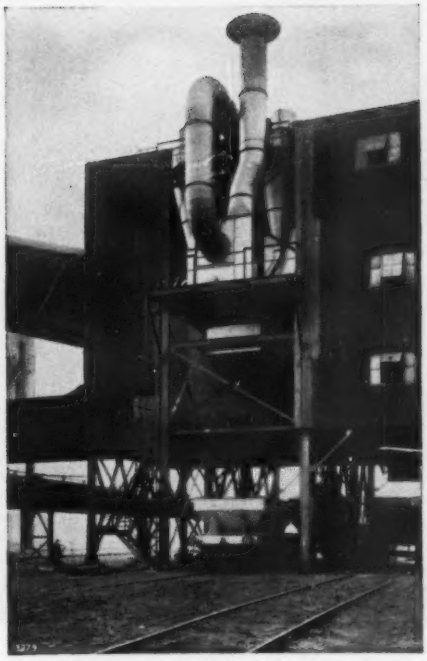
RELY ON THE EXPERIENCE OF G.E.C.

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND · WITTON-KRAMER DIVISION · BIRMINGHAM 6

388

DUST

from
Crushers • Screens • Elevators
Conveyors • Sinter Plant • Furnaces
Converters
and other sources in the Industry



Sturtevant High-efficiency Cyclones collecting coke dust. After collection the dust passes to surge hoppers from where it is loaded via chutes into wagons.

CONTROLLED AND COLLECTED by Sturtevant

DUST EXHAUSTING SYSTEMS

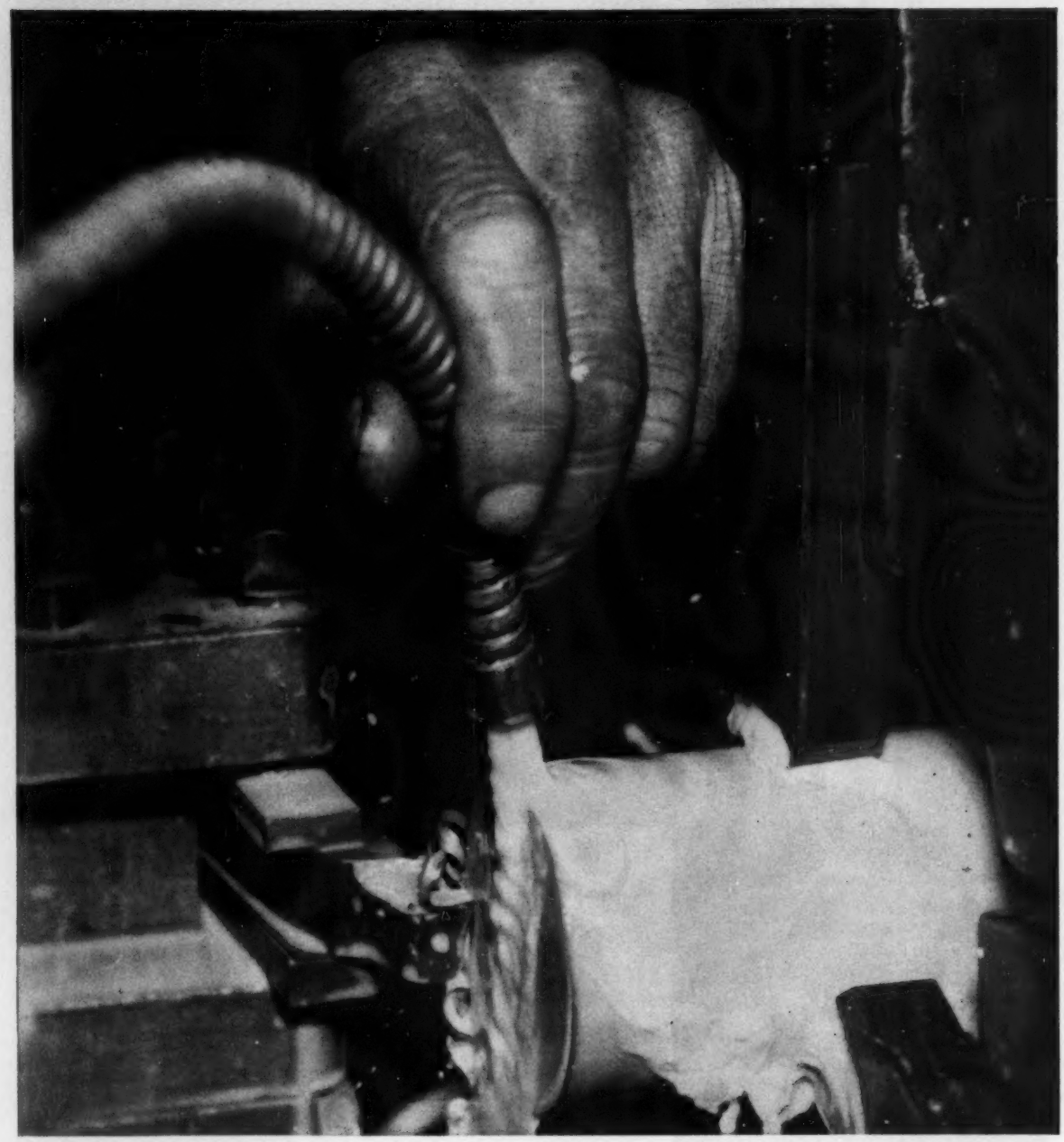
All types of dusts from all types of plants are handled by Sturtevant with advanced forms of collectors, which include Electrostatic Precipitators, High-efficiency Cyclones, Textile Filters, and Wet Scrubbers. Systems are designed for large or small applications and to meet the most stringent collection requirements at a fully economic rate.

Enquiries to our reference Z/101/S

STURTEVANT ENGINEERING CO. LTD., SOUTHERN HOUSE, CANNON STREET, LONDON, E.C.4

AUSTRALIA: STURTEVANT ENGINEERING CO. (AUSTRALASIA) LTD., 400 SUSSEX STREET, SYDNEY, N.S.W.

Shell achievement



One of Shell's recent achievements in Industrial Lubrication has been to reduce the risk of skin trouble for machine operators. Until the new Shell Dromus range, most modern soluble cutting oils contained phenolic compounds, which can cause skin irritation. They were used as coupling agents between the actual oil and the emulsifier. On high-speed machines, especially, the water evaporates and the emulsion concentrates. And that's when the trouble can start. Shell scientists found a better coupling agent, and made it work. And now, at no extra cost, management can reduce working risks for their staff. *Write for the book, 'Selecting Your Cutting Oils', to Shell-Mex House, London, W.C.2.*

SHELL

SHELL INDUSTRIAL OILS

Shell demonstration

Two clean, bright pennies are placed in beakers of oil, of equal performance level, one Shell Garia Oil 21, the other a conventional cutting oil containing sulphurised additives. After three hours at room temperature one penny is still bright and stain-free, the other heavily stained with black copper sulphide. The bright penny is from the beaker containing Shell Garia Oil 21, the blackened one from that containing the conventional oil. While these were just pennies they could have been bronze bushes in your machine tools—stained in less than half a shift. Sulphur is essential in heavy-duty cutting oils. Special additives in Shell Cutting Oils protect your machine tools and yet allow the sulphur to do its job. *Write for the book "Selecting Your Cutting Oils" to Lubricants Department, Shell-Mex House, London, W.C.2.*

DROMUS . . . PELLA . . . MACRON . . . GARIA

SHELL

SHELL CUTTING OILS

"STELLITE" RESISTS WEAR AT HIGH TEMPERATURES

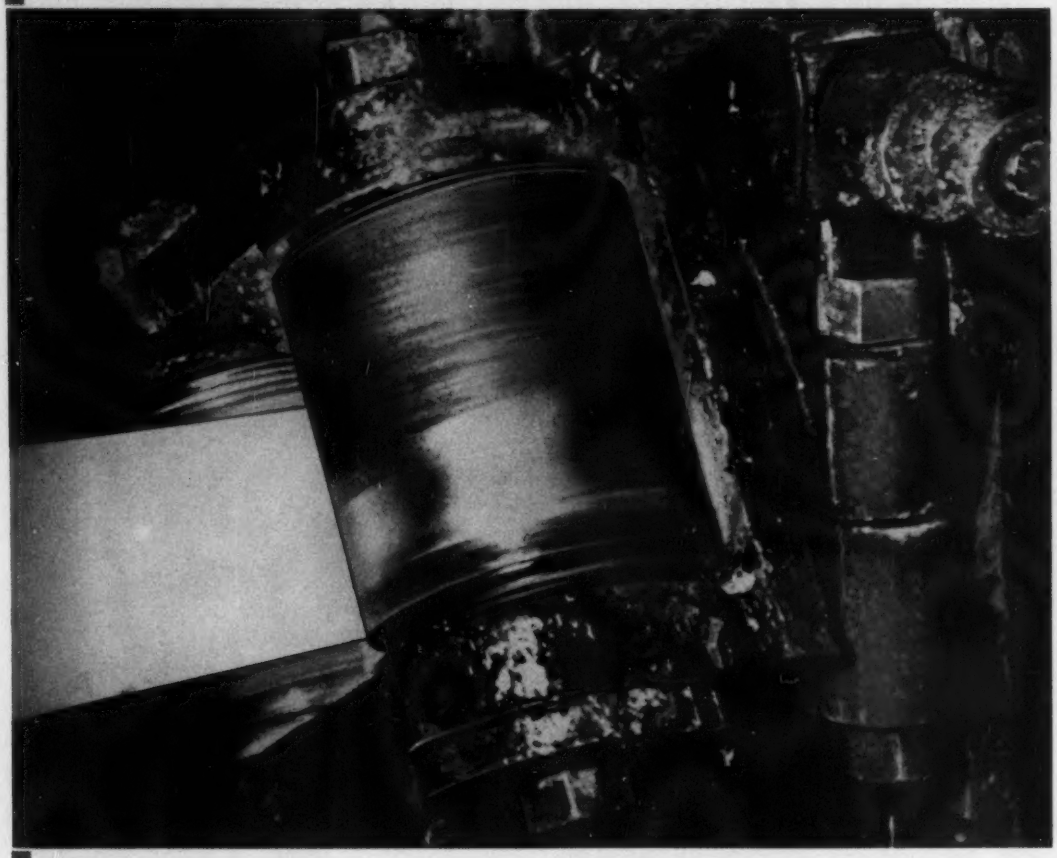


Illustration shows "Stellite" faced rolling mill guide in action

Throughout all branches of the Steel Industry Deloro Stellite alloys have proved to be extremely resistant to arduous conditions of abrasion and heat. Components protected with these alloys show a life increase of up to 500%. Applications include hot shear blades, ingot tong bits, twist rolls, etc.

"Stellite" is applied by normal welding processes, or the recently developed Spray-Fuse and Powder Welding methods.

DELORO STELLITE

Our area engineer will be pleased to call and give any advice you may require

DELORO STELLITE LIMITED · HIGHLANDS ROAD · SHIRLEY · SOLIHULL · WARWICKSHIRE
DELORO STELLITE DIV. OF DELORO SMELTING & REFINING CO. LTD. BELLEVILLE · ONTARIO · CANADA

The names "Deloro" and "Stellite" are registered trade marks

AD.NO.336

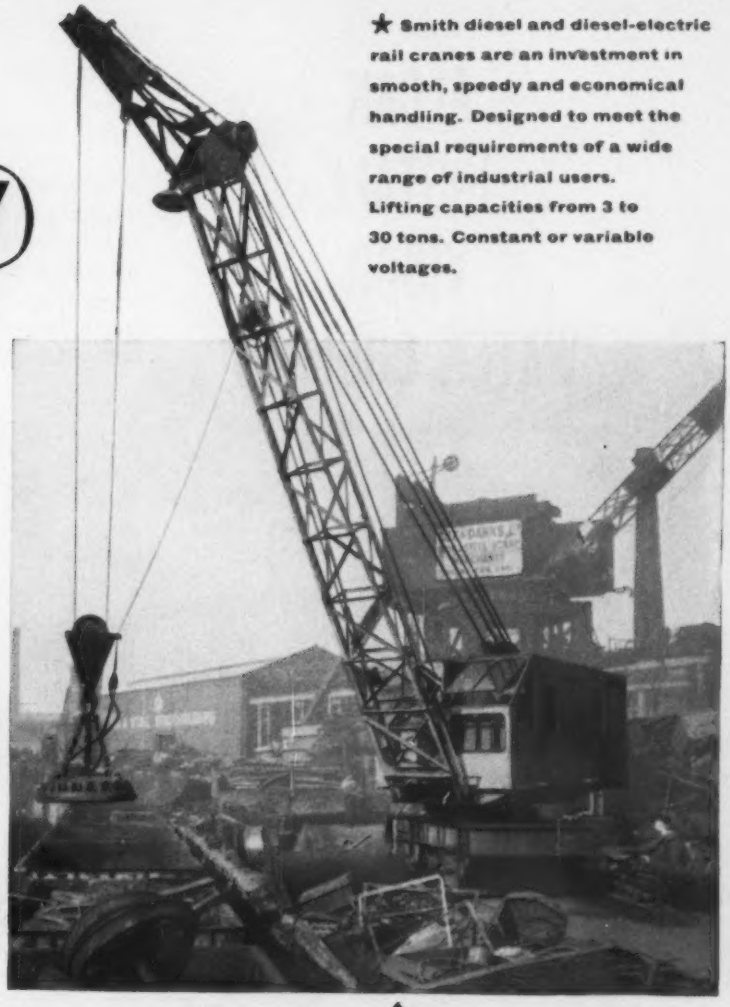
YOU'LL SEE

SMITH

DIESEL AND DIESEL-ELECTRIC CRANES

ON DUTY IN EVERY ASPECT OF MODERN INDUSTRY

★ **Smith diesel and diesel-electric rail cranes are an investment in smooth, speedy and economical handling. Designed to meet the special requirements of a wide range of industrial users. Lifting capacities from 3 to 30 tons. Constant or variable voltages.**



SMITH

Consult SMITHS first for Diesel and Diesel-Electric Cranes

THOMAS SMITH & SONS (RODLEY) LTD.

Crane and Excavator Works, Rodley, Leeds, England

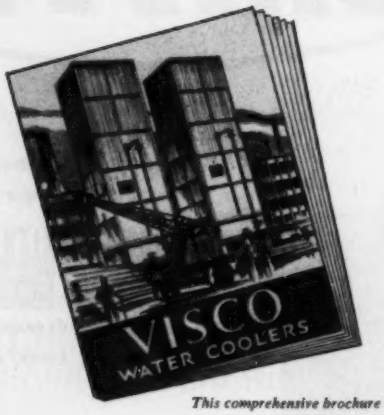
Illustration shows "Stellite" faced rolling mill guide in action

AD.NO.336

ALCAN INSTALL VISCO WATER COOLERS

ALCAN INDUSTRIES installed a VISCO 120,000 g.p.h. capacity Forced Draught Water Cooler as part of the water cooling system of their continuous rolling mill at ROGERSTONE. You can save time, water, space and money by consulting VISCO first on your water cooling projects. THE VISCO ENGINEERING CO. LTD., Stafford Road, CROYDON. Croydon 4181

Photograph by courtesy of Alcan Industries Ltd.



VISCO

Modern Water Coolers

This comprehensive brochure on Water Cooling FREE on request

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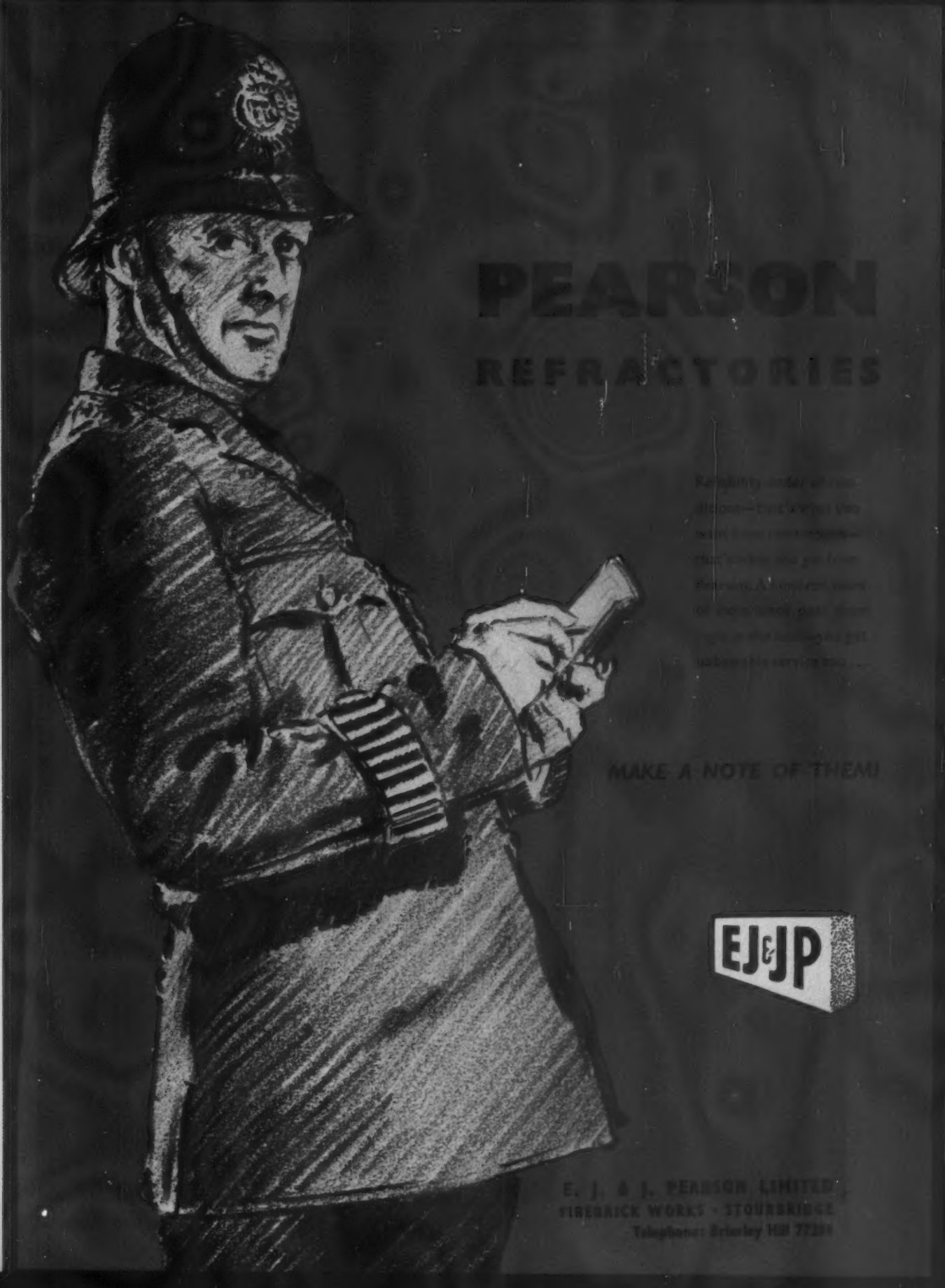
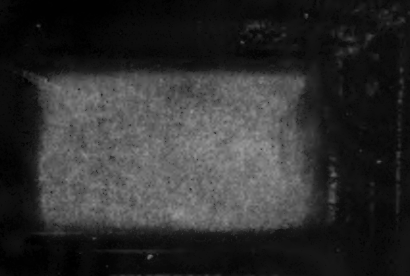
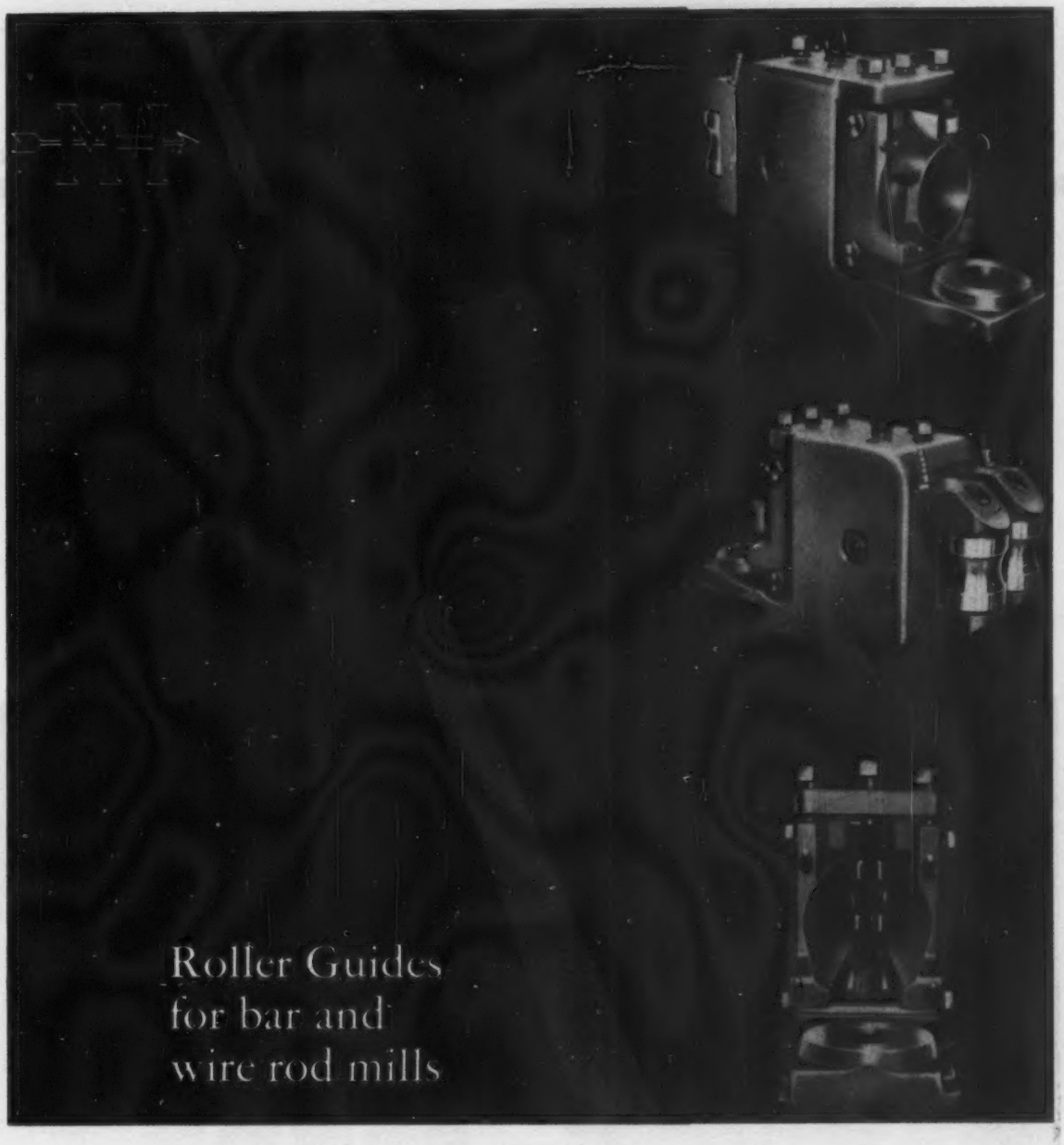


LARGE G.E.C. FURNACES



rely on the experience of G.E.C.



Morgårdshammar roller guides can be used for many sections such as leader and break-down ovals, squares, hexagons and octagons.

They can handle dimensions from about 3/16 in. (5 mm) round up to nearly 8 in. (200 mm).

You will obtain the following advantages with MH roller guides:

- INCREASED ACCURACY
- LESS SCRAP AND COBBLES
- REDUCED OPERATING COSTS
- INCREASED OUTPUT

For further information please apply to us for catalogues.

P.S.
In Scandinavia every bar and wire rod mill uses Morgårdshammar roller guides.

Swedish Quality

MORGÅRDSHAMMAR

HOLSET

FLEXIBLE RUBBER BLOCK COUPLINGS

CHOSEN BY
THE UNITED STEEL COMPANIES LIMITED

Appleby-Frodingham Steel Company
Samuel Fox & Company Limited
Steel Peech & Tozer
Workington Iron & Steel Company

CHARACTERISTICS OF HOLSET COUPLINGS

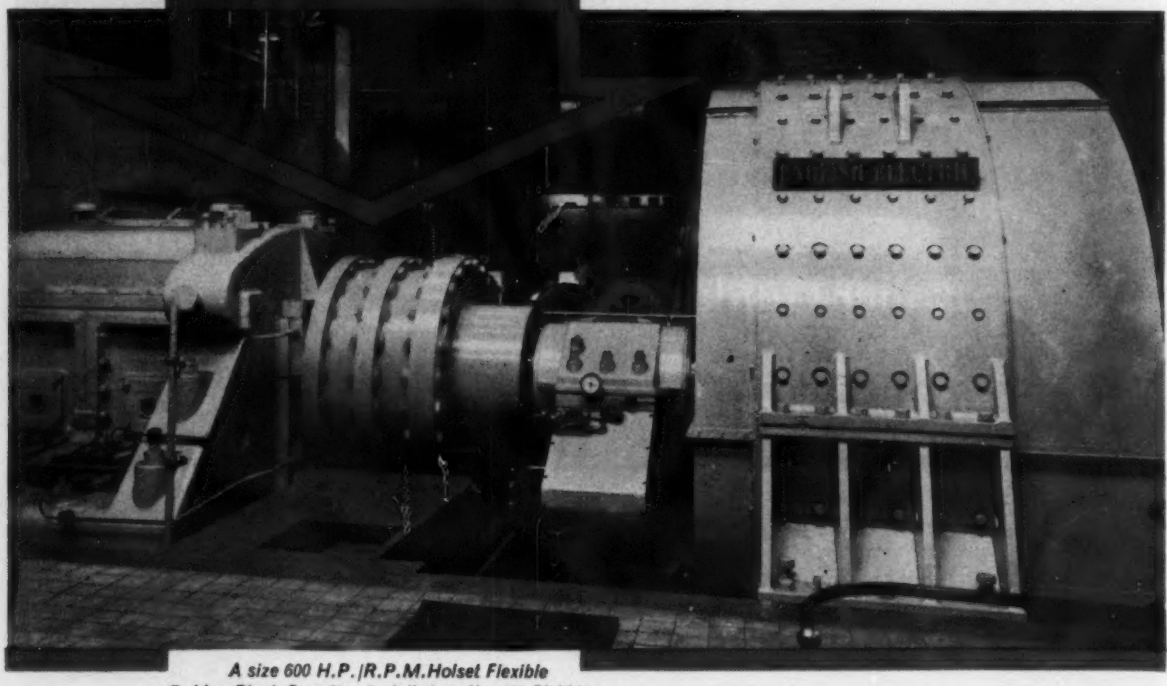
Can accommodate limited angular and parallel misalignment.

Absorb shocks and operate noiselessly under any conditions.

The multi-row arrangement of the blocks results in a small diameter and, therefore, a lower WR^2 value than any other torsionally resilient coupling.

No end thrust on the bearings of the connected shafts.

No lubrication or maintenance required.



A size 600 H.P./R.P.M. Holset Flexible Rubber Block Coupling installed on the 40" Slabbing Mill at the Stocksbridge Works of Messrs. Samuel Fox & Company Limited

THE HOLSET ENGINEERING CO. LTD
TURNBRIDGE, HUDDERSFIELD.
TELEPHONE HUDDERSFIELD 7480
TELEGRAMS HOLSET, HUDDERSFIELD

Fourteenth century carving of a sow and litter in Worcester Cathedral. Photograph by Ruth Meyler & F. C Sillar

50 MILLION PIGS GO TO MARKET!

In the early days of the industrial revolution manufacturers frequently looked for familiar and easily recognisable descriptions of their products. To the countryman transplanted into industrial surroundings nothing was more familiar than a pig; a fact which is emphasised by carvings in scores of old churches depicting pigs suckling their litter, rooting for acorns and playing the bagpipes. (Apparently this last pastime was forsworn by pigs many years ago because of unpleasant associations between bagpipes and pigs bladders.) Consequently, when iron from Blast Furnaces was directed into long troughs and from there into short and narrow troughs placed at right angles, a resemblance to sows suckling their appendaged litter led to the description of 'pig iron'.

This series of advertisements illustrates some of the 'ecclesiastical' pigs and emphasises the 50,000,000 'special' pigs which Warner and Company have supplied to Iron Foundries producing High Duty Castings.

WARNER WARNER WARNER

"Pioneers of Refined Pigiron"

KA

WARNER & CO. LTD., MIDDLESBROUGH

GWB

ARC MELTING FURNACES

in capacities from 250 lbs to 200 tons

Technical improvements evolved over many years with the installation of over 2,800 units are incorporated in the British built Arc Furnaces now being offered by G.W.B. When you discuss Arc Melting Furnaces with G.W.B. the most suitable furnace for your production programme and shop layout will be suggested from the wide range of designs available. Let G.W.B. advise you on your steel melting problems.

G.W.B. 36,000 kVA Steel Melting Arc Furnace with 24' 0" diameter shell

G.W.B. Submerged Arc Ferro-Silicon Smelting Furnace

GWB

FOR ALL THAT IS BEST IN
ELECTRIC MELTING AND SMELTING FURNACES

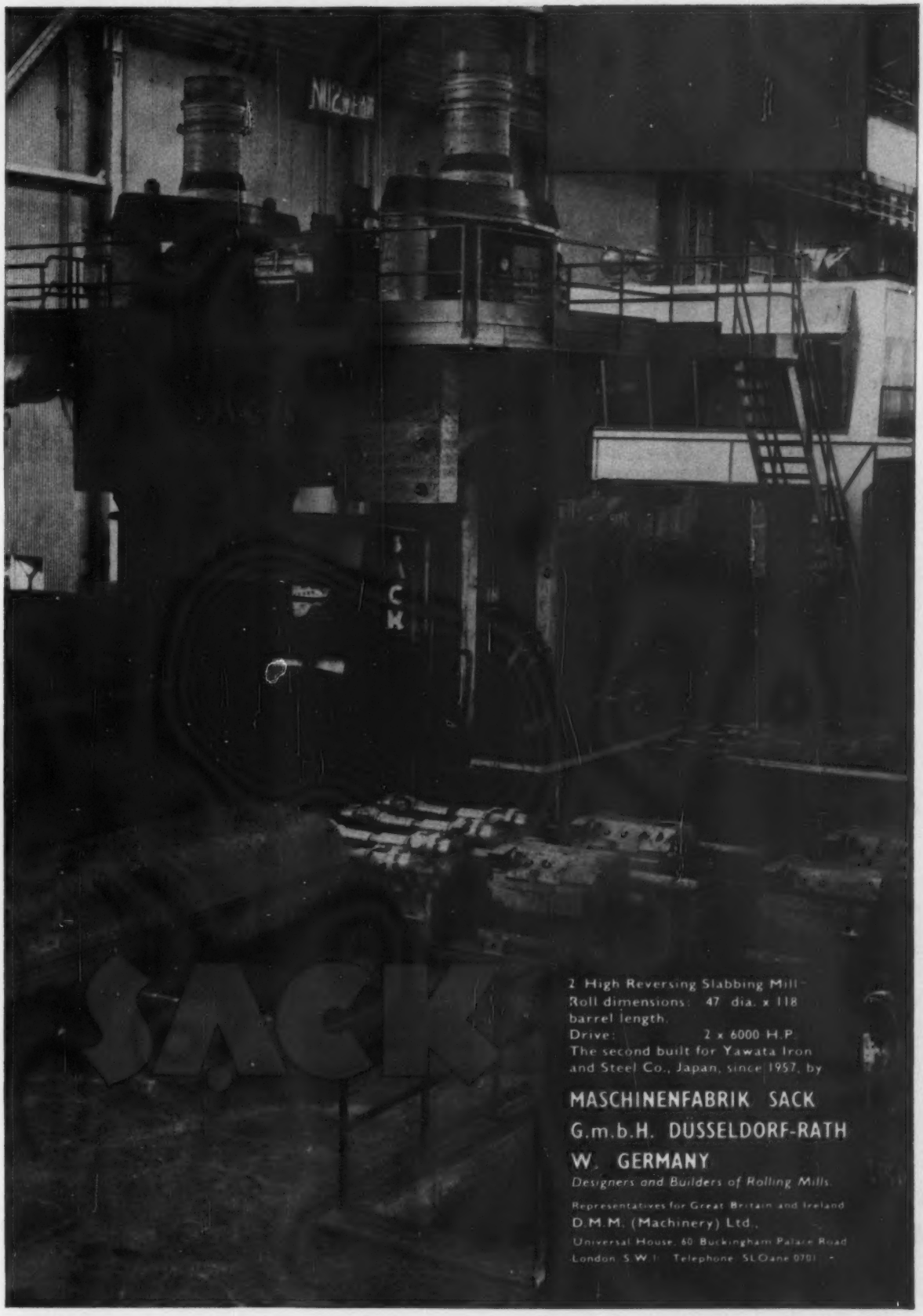
G.W.B. FURNACES LIMITED

P.O. BOX 4 · DIBDALE WORKS · DUDLEY · WORCS

Telephone: Dudley 55455

Associated with Gibbons Bros. Ltd. & Wild-Barfield Electric Furnaces Ltd.

GWB LD9



2 High Reversing Slabbing Mill
Roll dimensions: 47 dia. x 118 barrel length.
Drive: 2 x 6000 H.P.
The second built for Yawata Iron and Steel Co., Japan, since 1957, by

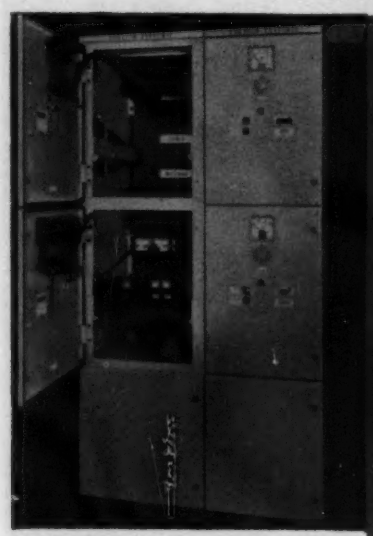
MASCHINENFABRIK SACK G.m.b.H. DÜSSELDORF-RATH W. GERMANY

Designers and Builders of Rolling Mills

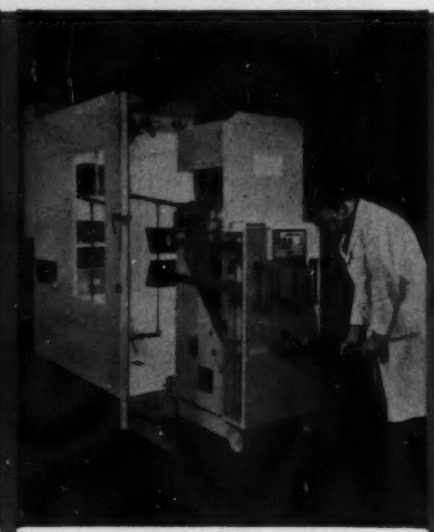
Representatives for Great Britain and Ireland
D.M.M. (Machinery) Ltd.,
Universal House, 60 Buckingham Palace Road
London, S.W.1. Telephone: SLOane 0701

SPRING IS IN THE AIR

SPRING-CLOSE OF ALL OUR MODERN RANGE OF SWITCHGEAR IS NOW AVAILABLE. YOUR ENQUIRIES ARE INVITED



Class 'M' Air-break Switchgear for 440V 31MVA systems.
A two-panel, double tier spring-close Class M23/22 415V 31MVA switchboard. The breaker has been removed from the top cabinet causing the safety shutters, covering the 'live' fixed contacts, to close.



Class 'E' Air-break Switchgear for 3·3kV 150MVA systems.
(250MVA breaker will shortly be available)
Operating a spring-close 3·3kV 150MVA circuit breaker. The side-panel of the housing has been removed to show the fixed cable and bus stalks on to which the 'ENGLISH ELECTRIC' patented 'Isolector' contacts engage.

Class 'CV' Ring-main unit.
Comprising oil-break compound-insulated breaker and fault-make/load-break spring operated switches for 6·6kV 250MVA systems.

'ENGLISH ELECTRIC'

switchgear

SWITCHGEAR DEPARTMENT, EAST LANCASHIRE ROAD, LIVERPOOL 10
The English Electric Company Limited, English Electric House, Strand, London, W.C.2.

SGL-55

ing-main unit.
ak compound-insu-
ult-make/load-break
witches for 6·6kV

SGL-55

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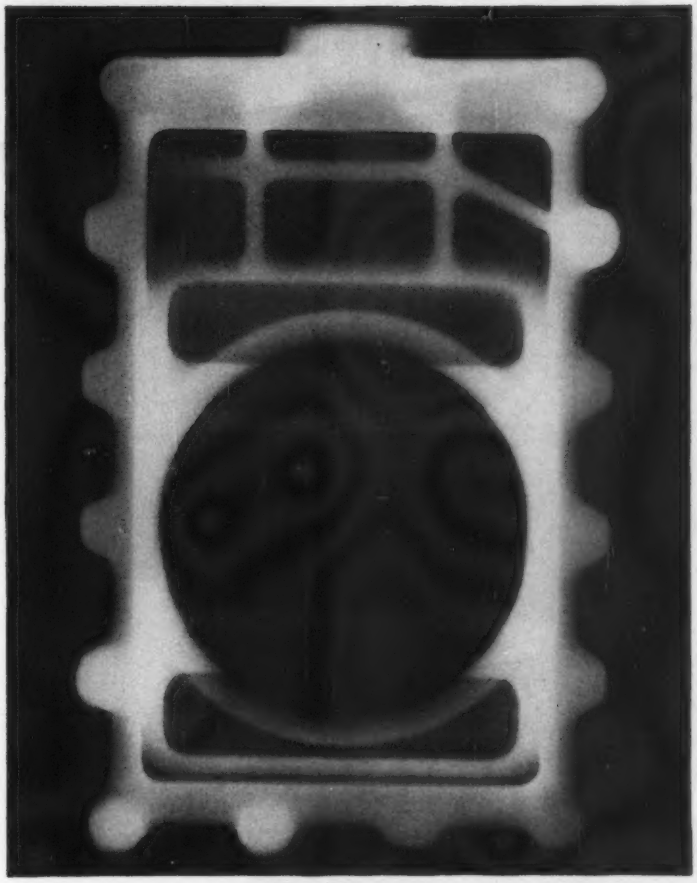


Where sections vary greatly . . .

. . . 2 films are better than 1

ILFORD technicians pioneered multiple film technique in industrial radiography. This has been graphically described as a "sandwich" of two or more films, and the technique gives vastly superior results where specimens with widely varying densities have to be critically examined.

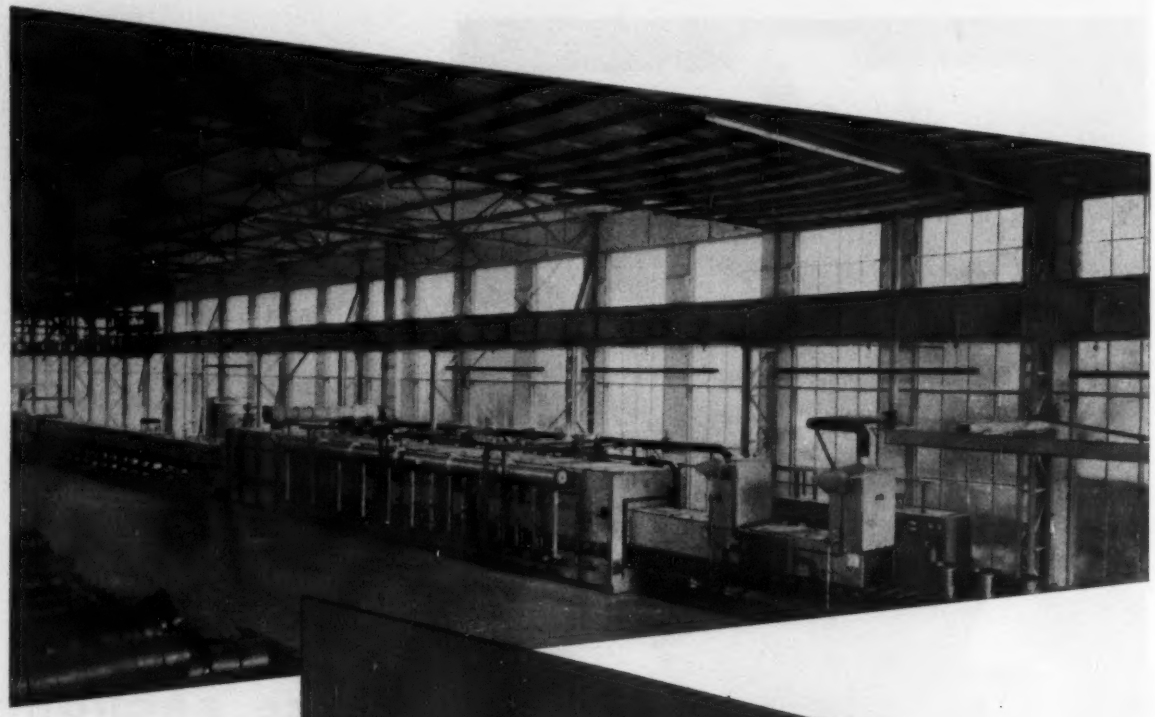
The "sandwich" consists of two or more films of different speeds loaded into a standard cassette for simultaneous exposure. Thick sections of the specimen register clearly on the faster film, and the thinner sections on the slower film. The effects of differential exposure can be accentuated by using lead screens in the "sandwich". The technique can also be used for making duplicate radiographs by using two films of the same speed.

Choice of the appropriate ILFORD Industrial X-ray films obviously depends on the subject, the tube voltage and the presence or absence of screens. Full details of film choice and voltages, as well as lead screens, will be forwarded by request.

For improved radiographic examination

ILFORD INDUSTRIAL X-RAY FILMS, CHEMICALS, CASSETTES AND LEAD SCREENS

ILFORD LIMITED · ILFORD · ESSEX



NASSHEUER

continuous bright annealing

FURNACES

(Patent No. 779669)

INCREASE PRODUCTION AND QUALITY LOWER MAINTENANCE AND OPERATING COSTS, OUTPUT UP TO 5 TONS PER HOUR, GAS OR ELECTRICALLY HEATED

Suitable for:—

Strip in Coils
Wire Coils
Bar Materials
Sheets in batches or singly
Tubes
Ferrous or Non-Ferrous material

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THE INTERNATIONAL CONSTRUCTION CO., LTD

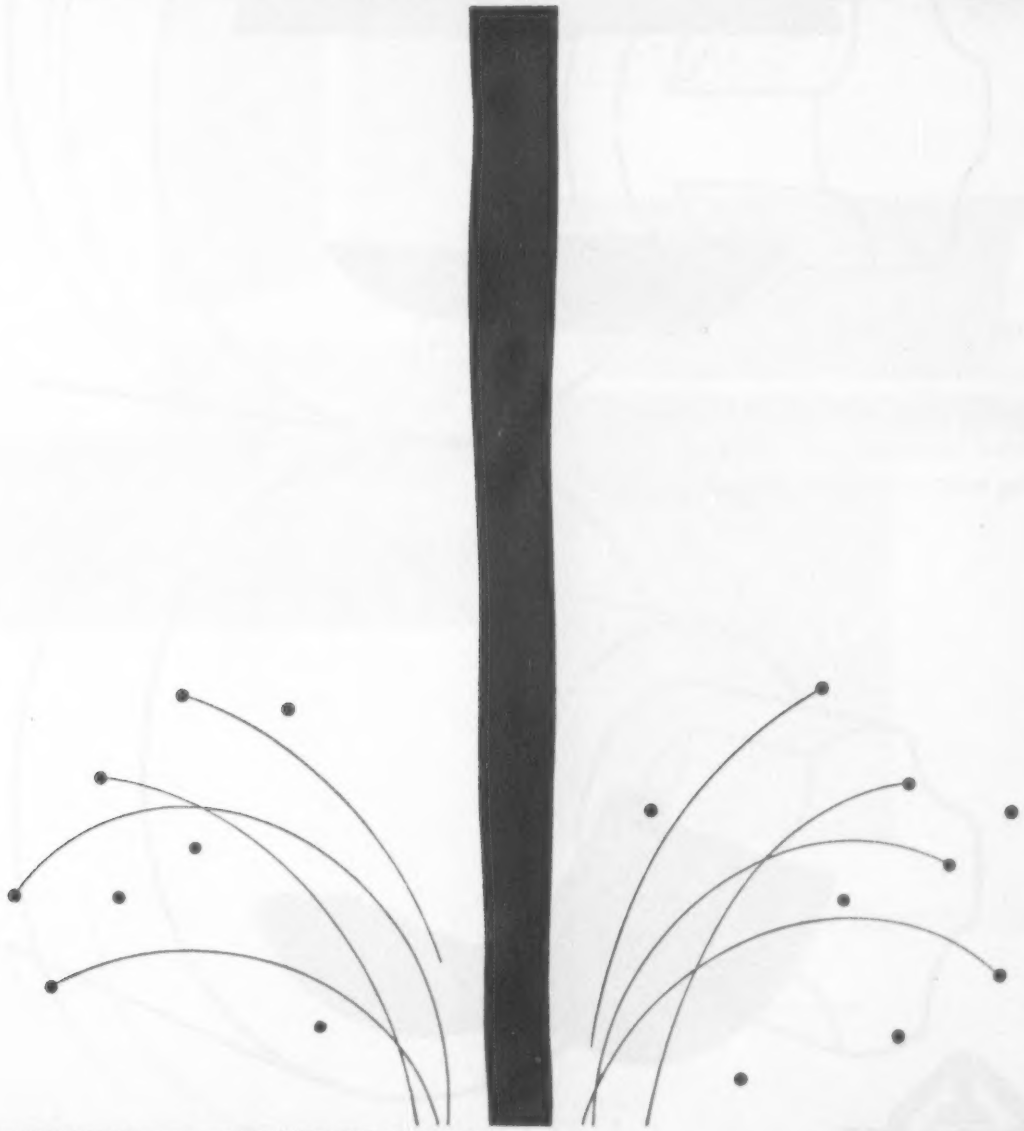
56 KINGSWAY · LONDON W.C.2

Ferro alloys* by the ton!

If you are in the Steel Industry and are in the market for ferro alloys of any type and in any quantity, our products, speed of delivery and terms of business would interest you. In particular we are bulk suppliers of the following: 45-50% FERROSILICON · SILICO MANGANESE LOW CARBON FERROCHROME · HIGH CARBON FERROCHROME · REFINED FERRO-MANGANESE.

A representative of our Alloys Division calls regularly on your Buying Department but he will be happy to meet you whenever you have a particular requirement to discuss with him.

UNION CARBIDE



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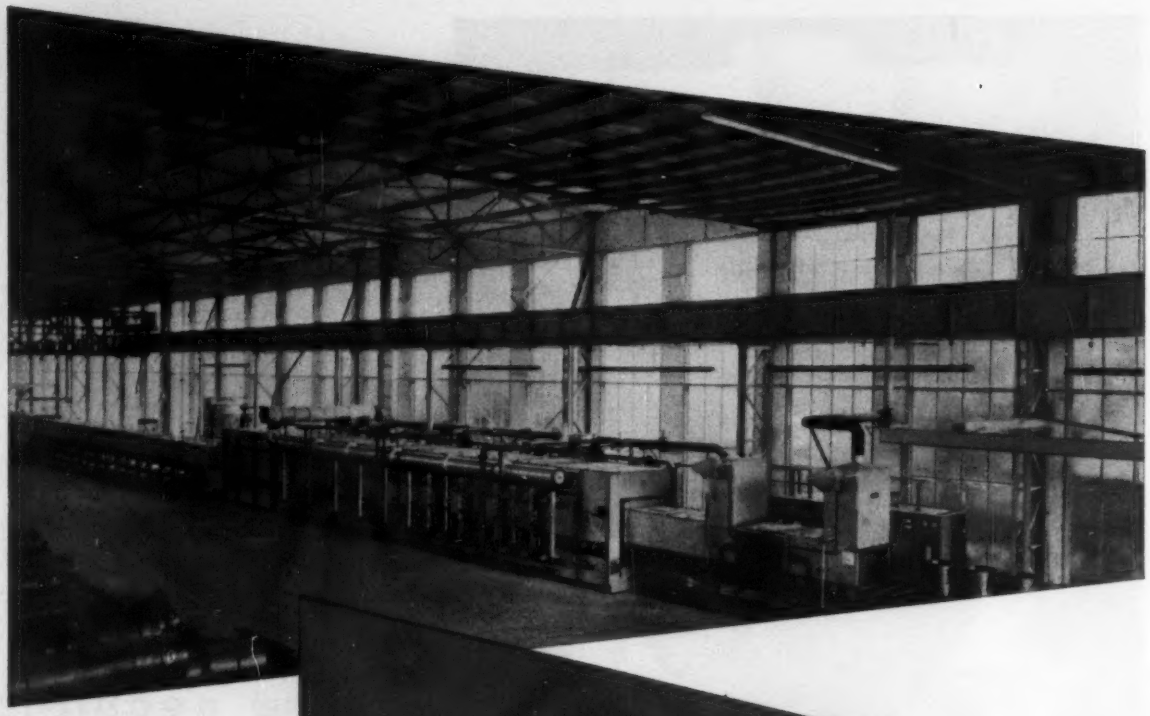

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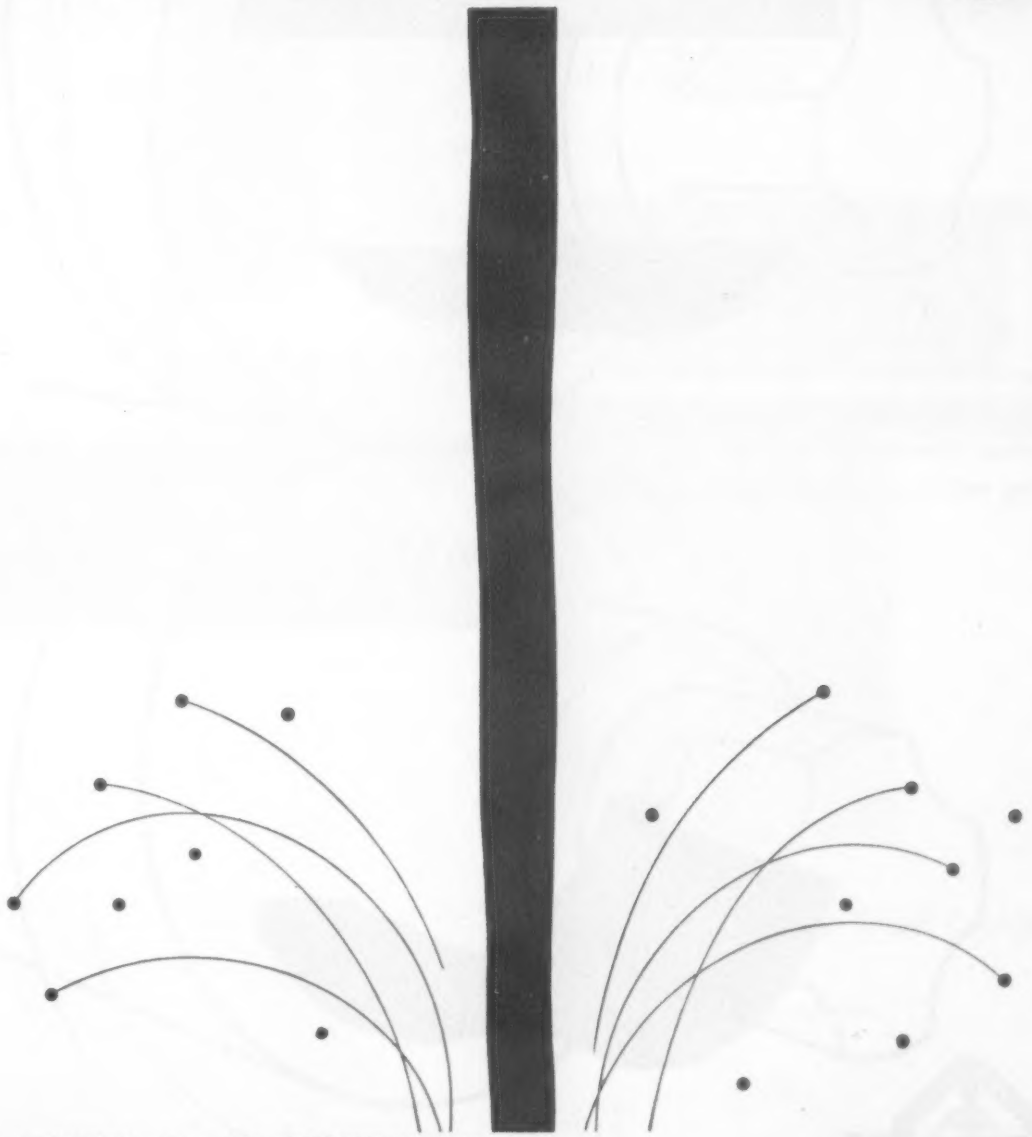

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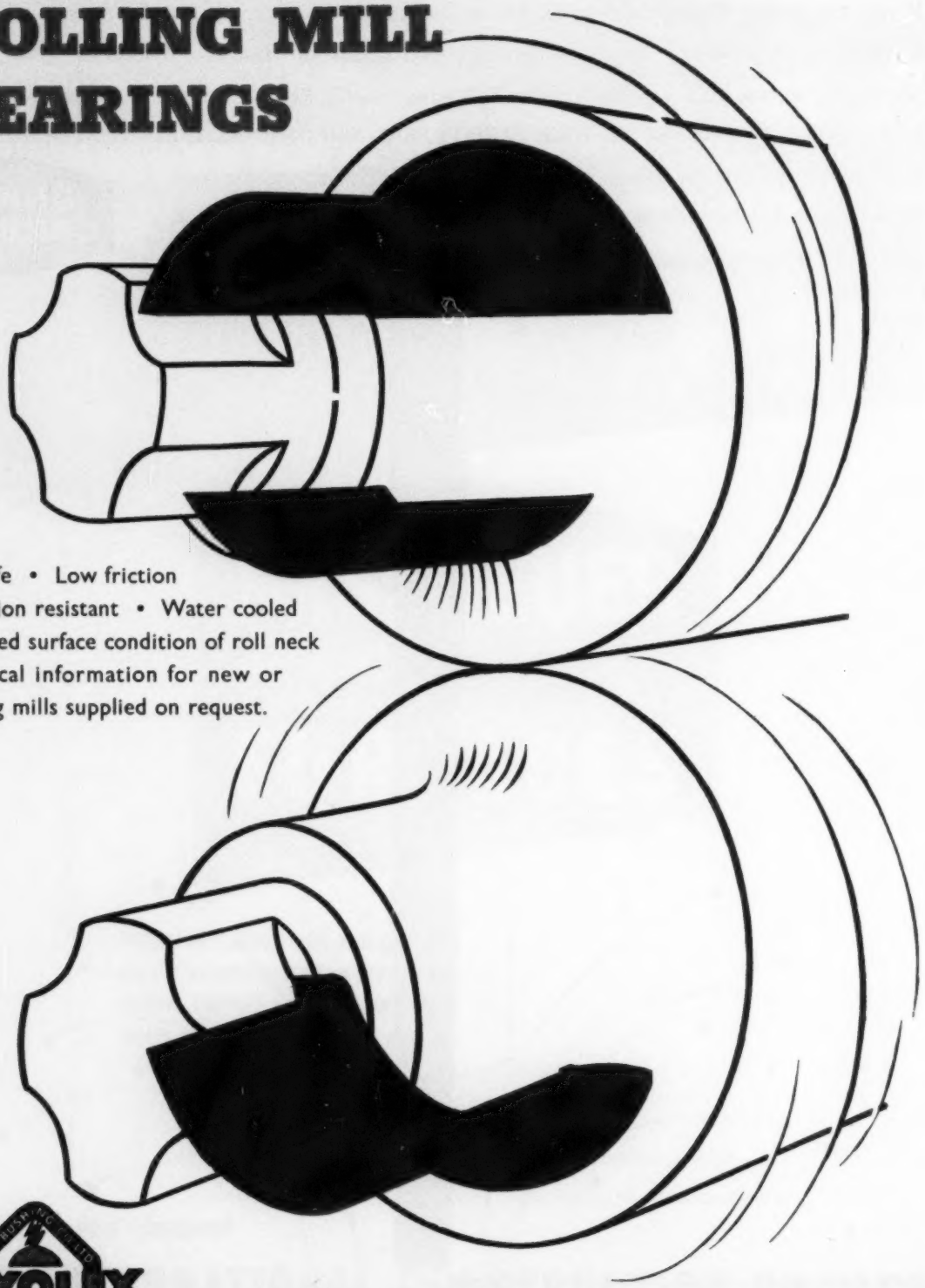

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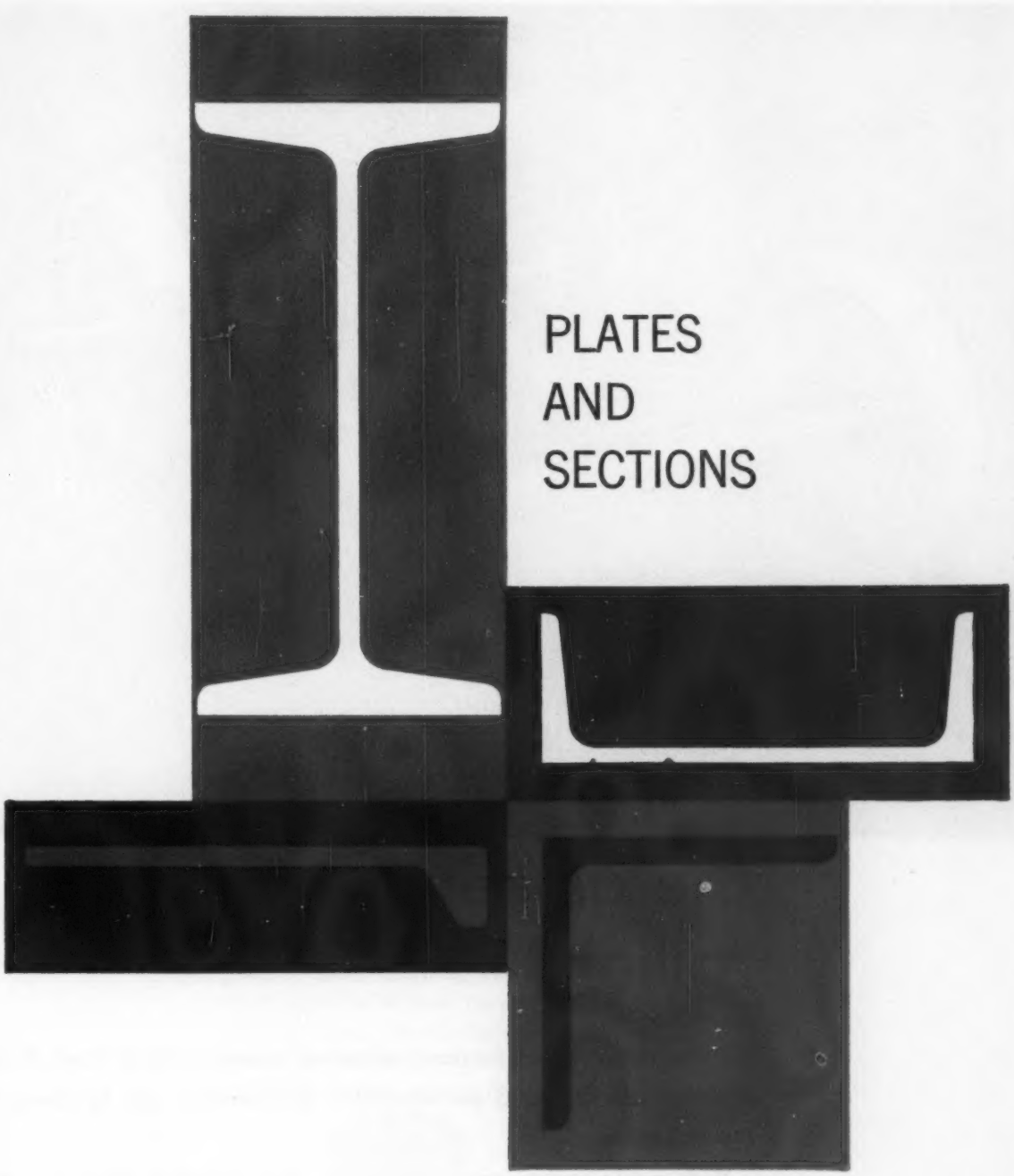

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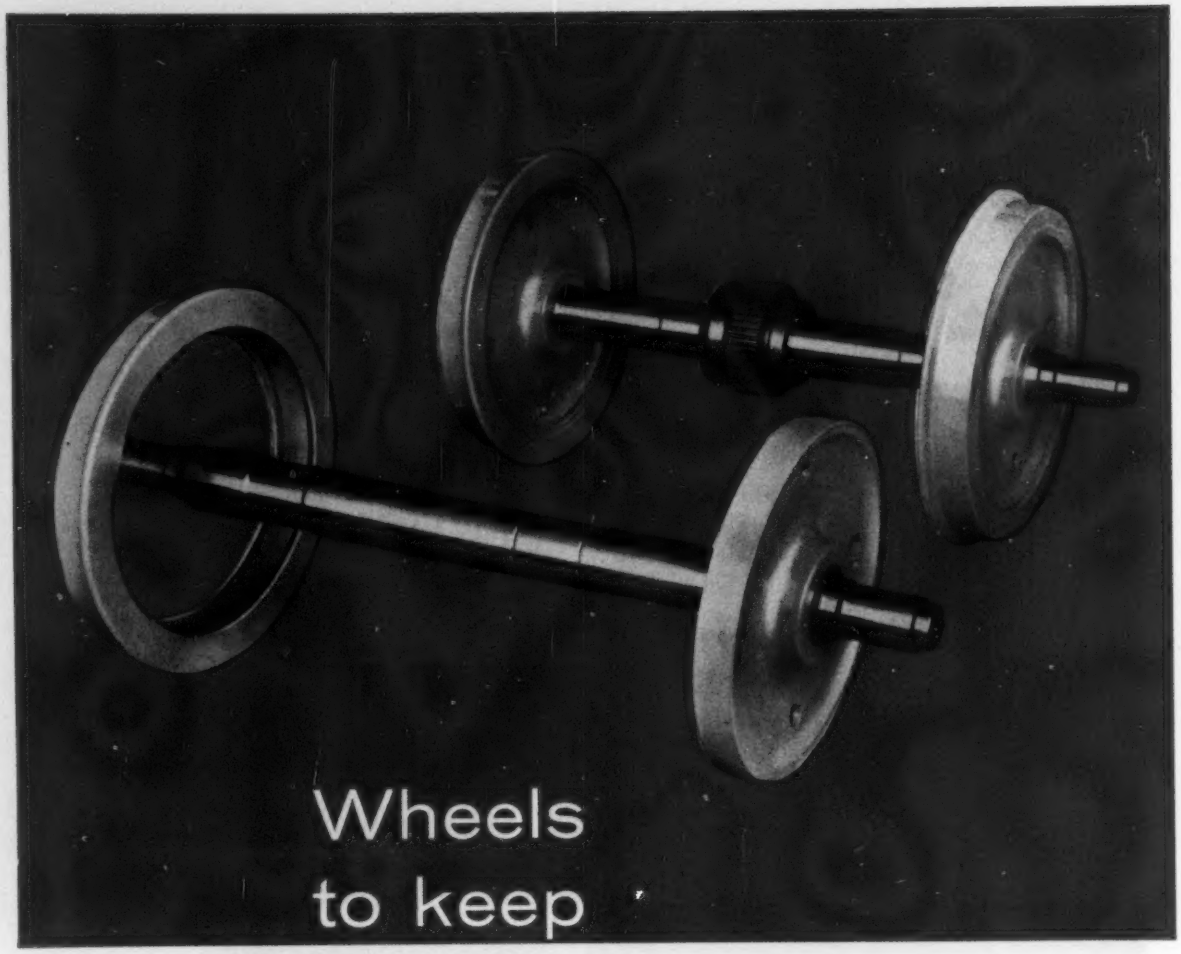

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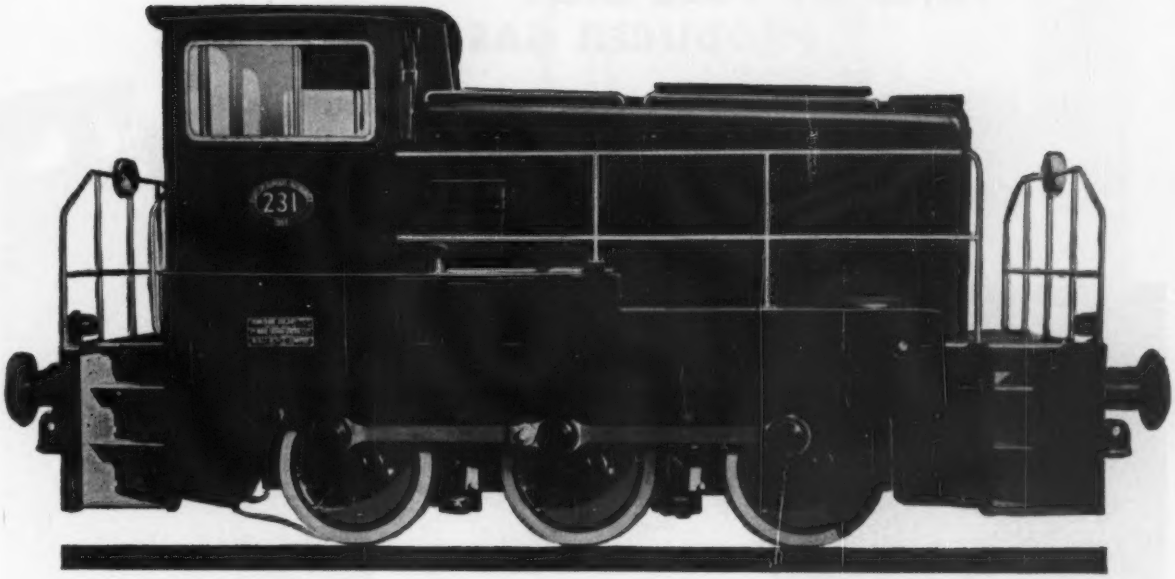

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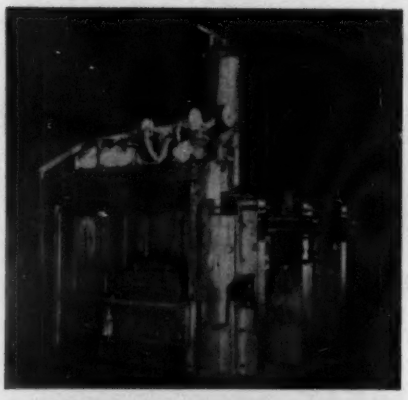

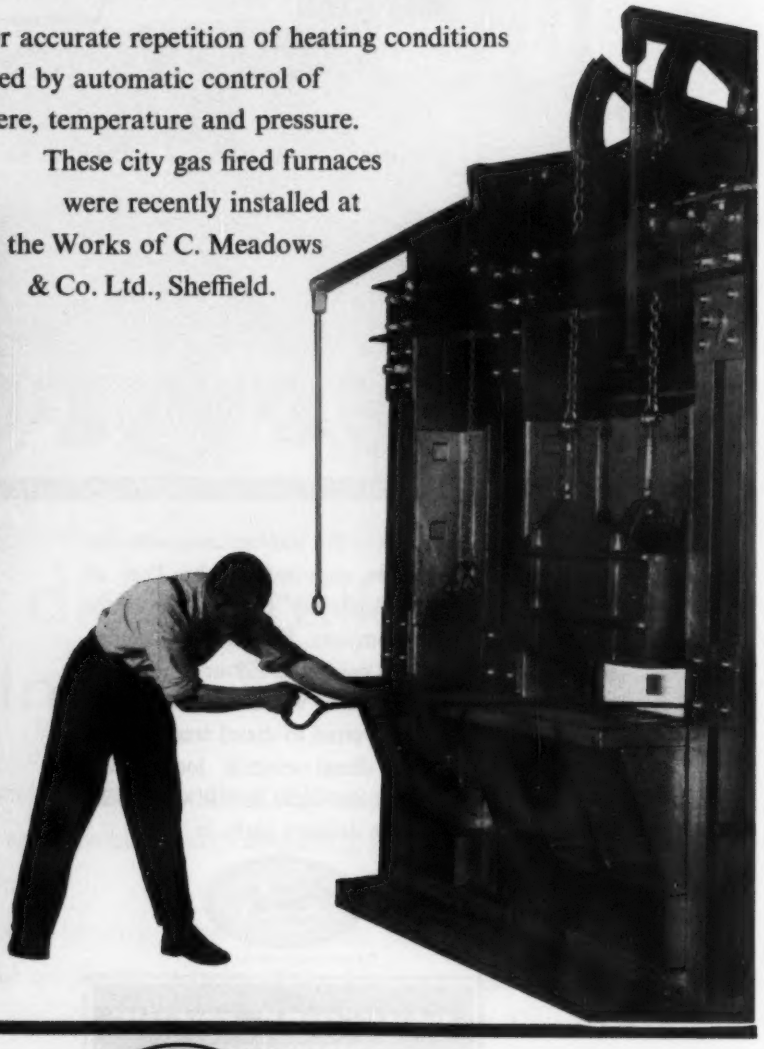

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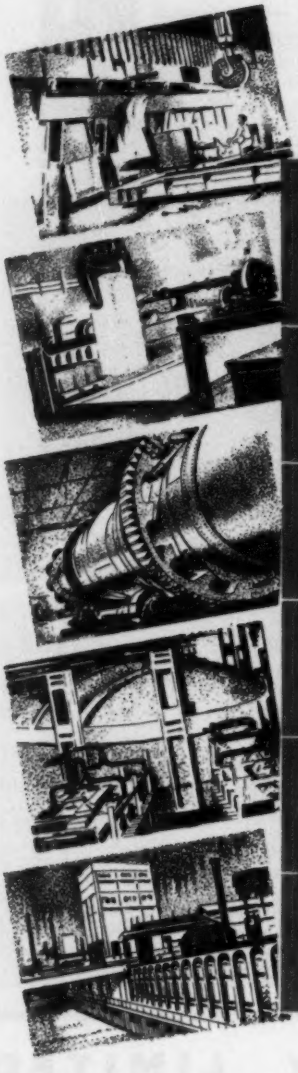

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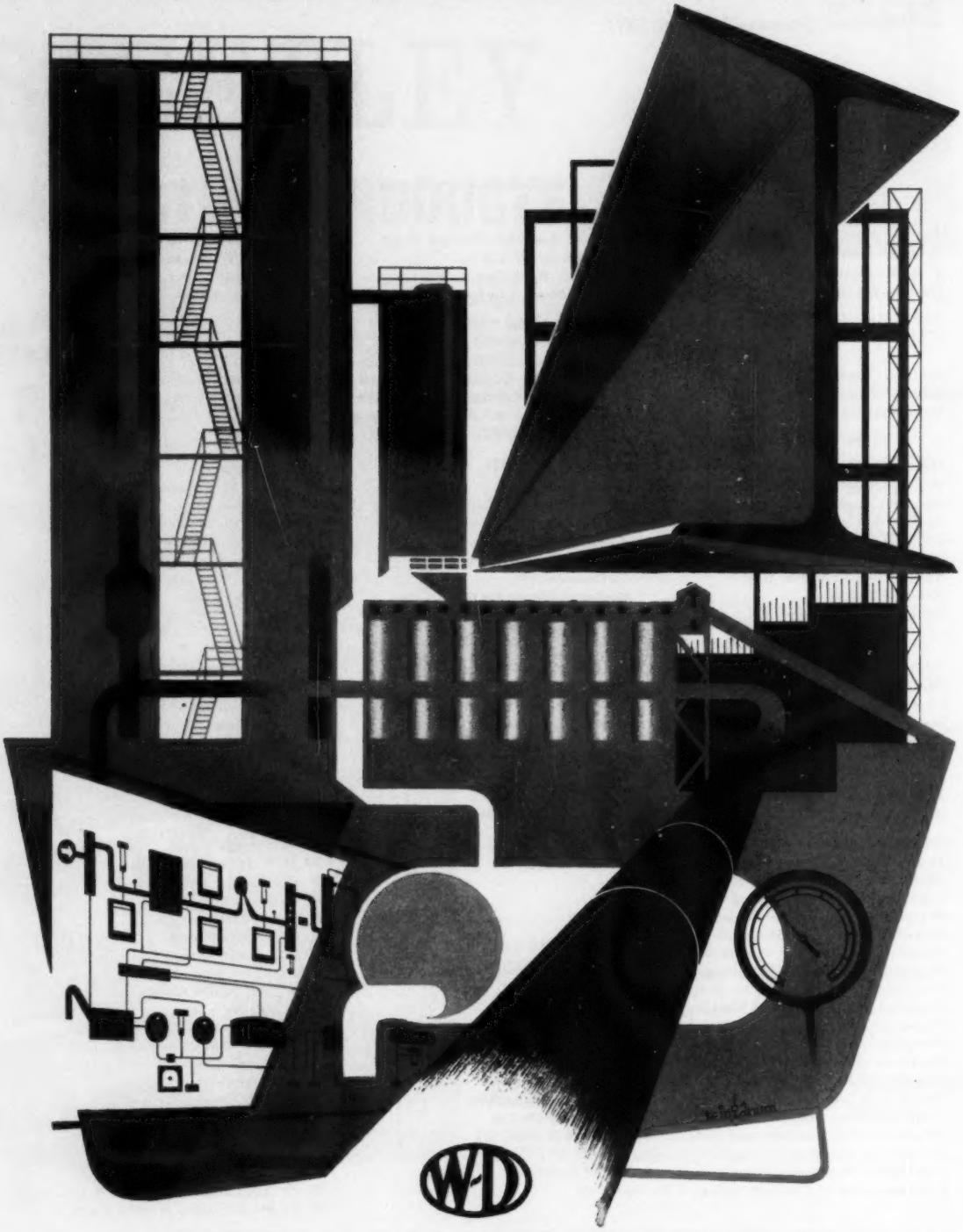

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Journal of The Iron and Steel Institute

Contents

THE IRON AND STEEL INSTITUTE

Presidential address: Steel in an expanding Britain 117
Sir Charles Goodeve

Review: 'The determination of gases in metals' 124
C. J. Smithells

Reconstitution of the light section mill at Round Oak Steel Works Ltd 126
W. S. Walker, J. F. Whitfield, and G. A. V. Russell

Vacuum steelmaking 131
A. M. Samarin

The examination of oxide scales on iron–chromium alloys by X-ray scanning microanalysis 142
G. C. Wood and D. A. Melford

English bloomeries (1329–1589) 149
R. A. Mott

An effect of composition on the macrostructure of ingots of a low-alloy steel 161
T. B. Smith, J. S. Thomas, R. Goodall, and R. T. Allsop

Education 164

Co-operation with sister institutions 180

DISCUSSION ON PAPERS

Discussion at the Autumn General Meeting, 1960, on martensite 165

News 181 **Translations** 184 **Abstracts** 185

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SIR CHARLES GOODEVE, O.B.E., D.Sc., F.I.M., F.R.S.

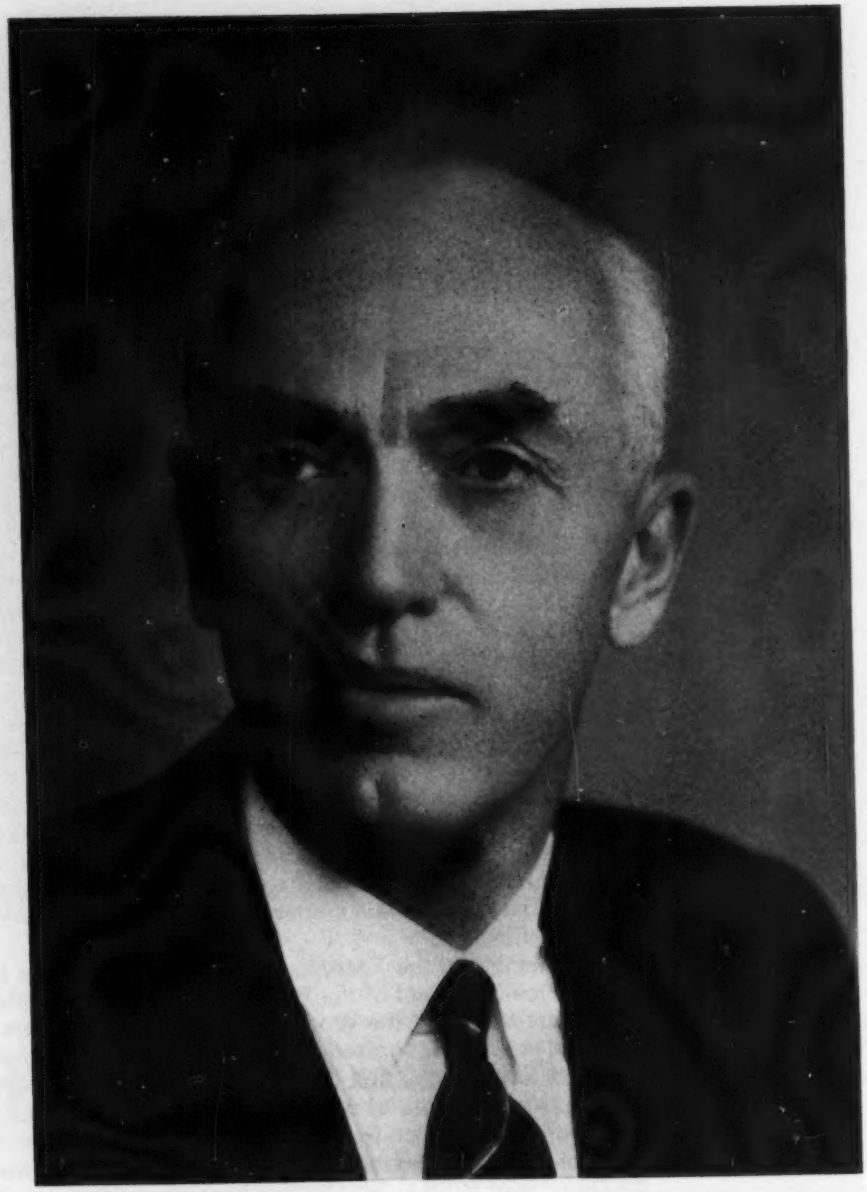
CHARLES GOODEVE was born in Canada in 1904. He entered Manitoba University in 1920 and after graduation spent three years engaged on research on electro-chemistry. In 1927 he was awarded a scholarship to University College, London, where he remained until the outbreak of World War II. He was appointed Lecturer in Physical Chemistry in 1930, and in 1937 became Reader in Chemistry. At University College his researches were mainly concerned with physical chemistry, and especially with photochemistry, absorption spectra, and reaction kinetics. He was elected a Fellow of the Royal Society in 1940. During World War II he served in the Royal Navy. He played a highly responsible part in countering the magnetic mine, and later developed and produced the 'Hedgehog' anti-submarine weapon. From 1942 onwards Commander Goodeve, as Deputy Controller, was in effective control of the whole research and development programme of the Royal Navy, and it was for his services in this connexion that he was knighted in January 1946.

Sir Charles left the Admiralty to become Director of the British Iron and Steel Research Association on its foundation in 1945. To this was added the honorary post of Research Director to the British Iron and Steel Federation. He was elected President of the Faraday Society in 1950, and President of the Chemistry Section of the British Association for the Advancement of Science in 1956. His services to the iron and steel industry and to chemistry were recognized in August 1956 when the University of Sheffield conferred on him the honorary degree of Doctor of Science.

He is a member of the Technical Advisory Panel of the Iron and Steel Board, Vice-President of the Parliamentary and Scientific Committee, and a Past-Master of the Worshipful Company of Salters.

Sir Charles early recognized the importance to industry of operational research, and was the first Chairman of the Operational Research Society. As a member of the Research Advisory Council to the British Transport Commission from 1948 to 1958 he took a special interest in the application of operational research to road and railway problems.

As Director of BISRA, Sir Charles became an Honorary Member of Council of The Iron and Steel Institute since 1945, and he has served as a Vice-President since 1956. He has been elected President of the Institute for 1961–62.



Sir Charles Goodeve, O.B.E., D.Sc., F.I.M., F.R.S.
President 1961–62

PRESIDENTIAL ADDRESS

Steel in an expanding Britain

Sir Charles Goodeve, O.B.E., D.Sc., F.I.M., F.R.S.

Presidential Addresses are commonly occasions for attempts at forward thinking. This will be no exception, but it will not be based on long and special experience in our iron and steel industry. Rather will it start from the broad background of the country itself because the futures of steel and of this country are closely linked. It will also be based on some current technological trends.

To those about to indulge in crystal gazing it is salutary to review previous efforts; indeed, I can use one such effort as a starting point. A few years ago I put together from many sources a comprehensive analysis[1] of the physical and geographical advantages of this country and came to the conclusion that this is a rich and well placed country, a land of opportunity awaiting only the full realization of this by the people who dwell herein. Has the picture of the advantages changed? Are the people, through their industries including steel, exploiting their opportunities? Each year for the next five years steel production in the UK is expected to increase by about one million tons, that is by 4% per year, and the capacity by nearly twice this rate. Could not our sales more closely follow the capacity? What about the period beyond? Steel is crucial to the economy of this country and in turn depends on it.

I hope I may be forgiven if I repeat in outline the main part of the previous analysis. It was based on a consideration of the island of Great Britain without its people; rather in the way a committee sent to an unpopulated island might approach its report. The advantages were considered under five main headings, soil and climate, mineral resources (including energy), access to the sea, internal communications, and, finally, geographical location, all overlapping but otherwise useful divisions. This time I propose also to consider a sixth advantage, Britain's position in the Commonwealth.

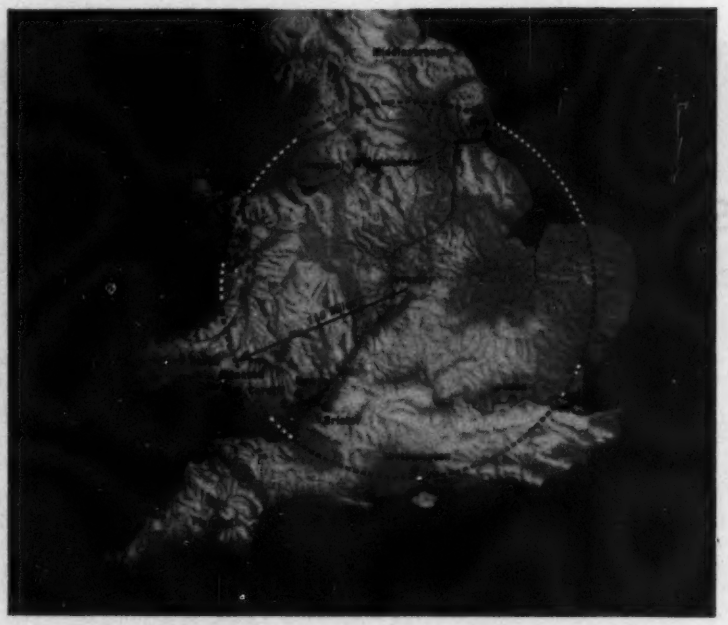
Soil and climate are what make it possible or agreeable for people to live. Our soil is generally of good quality and the rainfall and sunshine sufficient to make possible a productivity per acre almost as high as any land in the world. With the addition of foodstuffs conveniently brought from the continent of Europe and from the Commonwealth, we could provide a good standard of food and other living conditions for up to 75 million people. In most parts there is an ample supply of water for industrial and domestic purposes.

In mineral resources, this country is not as excitingly rich as many others, but it is far from being poor. It has some of the finest coal deposits of any country, including coking coal. Although it is somewhat difficult to mine, supplies are ample for several hundred years. There are no appreciable amounts of oil or natural gas, fuels which are now dominating the world energy situation. There is still a fair amount of iron ore but no ferro-alloys. The country is particularly rich in building material: that is, material for making cement, bricks, etc. It has also plenty of limestone, dolomite, china clay, salt, gypsum, and other materials which form the basis of the heavy chemical industry. This country has a range of geological formations such as are usually only found spread out over an entire continent. As a consequence, it has a wide variety of minerals situated close together and the problems of assembling them for production purposes or for utilization are less than in most countries.

Britain's greatest advantage is probably that of easy access to the sea through its many ports. Water transport is not only highly flexible, requiring no roads or tracks, but it is, for materials of medium or low value per ton, by far the cheapest form of transport, costing about one-tenth as much as rail or road. This large difference in cost is inherent in the two systems of transport and is unlikely to be altered appreciably in the future. As can be seen from Fig.1, no factory can be built in England farther than 90 miles from a port through which it has access to the world's resources in raw materials. All the deficiencies in local mineral resources can readily be made up in this way.

Perhaps the most important consequence of easy access to the sea is that an industry in this island has, through its many ports, access to the largest potential market for its goods of any manufacturing community. This point, of course, depends on definition. A manufacturer's market can be measured by the number of consumers inside an area where his price is or can be competitive. That price depends on initial cost plus the cost of transport. Cheap sea transport gives a manufacturer in this country access to a much greater number of potential customers than a corresponding factory in the middle of the United States, Germany, or Russia. Geographically, at least, Britain has the enormous market of Europe on her doorstep.

These three advantages combine together with the favourable topographical features of the country to produce a fourth advantage, easy internal communications. The island, while being able to support a closely knit and densely populated community, is also able to



1 *Main ports for Britain's manufacturing areas. Coventry is about as far from the sea as it is possible to be, yet it has two ports within 90 miles and six more within 110 miles*

encourage individual specialization, an essential to high productivity, because of the short distances and easy terrain over which people and things can be transported. Manufacturers nowadays depend on each other to an extent unknown a generation or so ago and this interdependence is increasing as technology advances.

The fifth advantage is the central location of this country on the globe. The world has need for a centre to carry out certain commercial and financial operations. It also needs a centre of trade in commodities, such as metals, diamonds, and furs in order to introduce stability and quick response into the world's supply and demand situation. It needs a centre where the maximum amount of scientific and other knowledge and information can be collected and made available. It needs a centre to collect together and develop the best ideas of social and political organization arising in Europe, America, or Asia. Yet at the same time this centre must not be part of America, Continental Europe, or Asia if it is to be impartial.

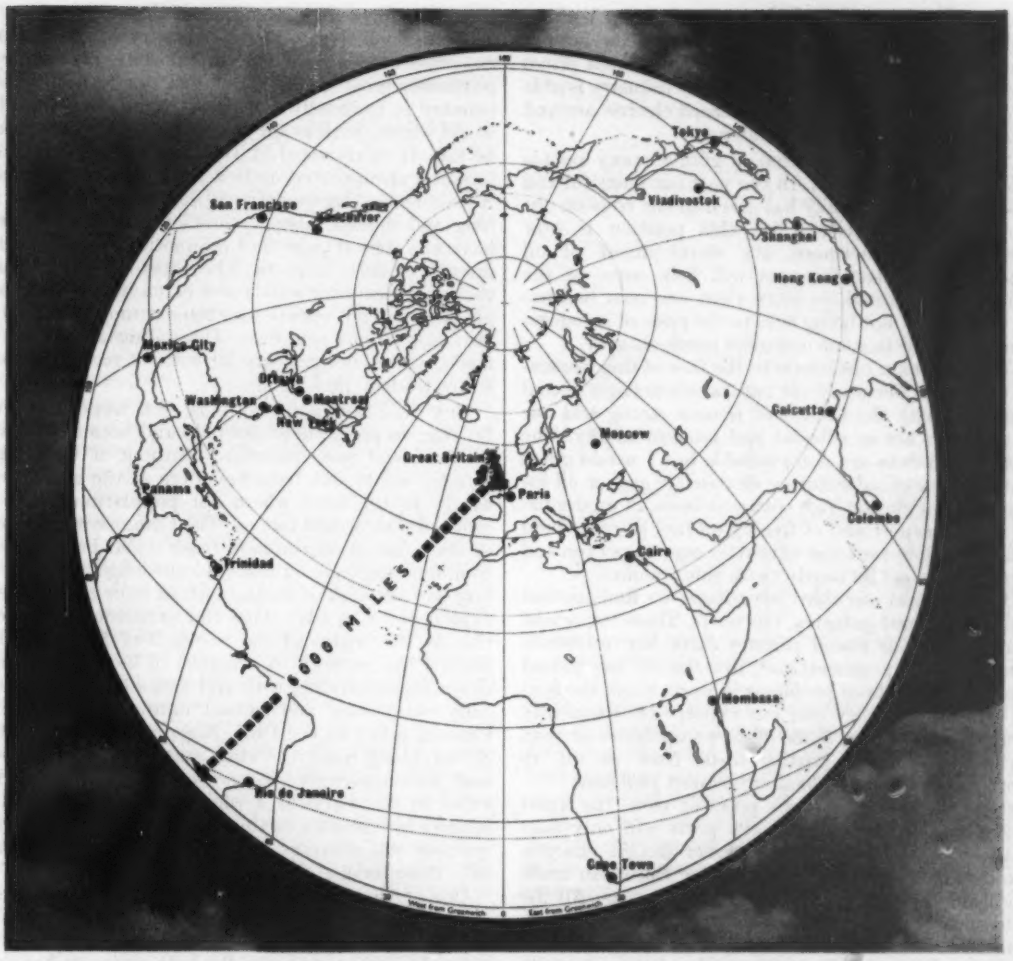
The position of Great Britain is outstandingly good in this respect. It lies effectively at the centre of the populated land areas of the globe as is shown in Fig.2. This map is an 'azimuthal equidistant projection' about London as a centre and shows the distance from London along the shortest route, the 'great circle route', to any point on the hemisphere. It is perhaps easier to visualize this map if it is said that it is very similar to the view of the world that a space traveller would have from a point a few thousand miles above London. It is to be noted from the map that, with the advent of air travel, we have become remarkably well placed, in that we are within non-stop flying distance of the capitals of the countries representing over 90% of the world's population. It is surprising to note that even Tokyo and Cape Town are in our hemisphere.

This then is a picture of a comparatively rich country. It should be able to compete commercially with Russia, a country with vast mineral resources but with these resources spread over great distances and all of them a long distance from the sea. There are parts of Western Europe that are richer in one or two of the elements considered above but none that is richer in all five. The United States is often looked upon as the richest country in the world, but it is deficient in respect of some of these elements. Its energy and mineral resources are very great, but as in Russia, rather widely scattered. Its climate is inferior to that of the UK (its weather is perhaps better!) and only a proportion of its manufacturing industry has ready access to the sea. Geographically it is far from the centre of the world.

EXPLOITATION OF NATURAL RICHES

Let us now look at the other side of the picture, the extent to which we have exploited these riches. If they have been fully exploited then the production of this country including that of steel will be approaching its ceiling. If not, then the future will be in the hands of the people. A more detailed analysis shows that the weaknesses are offset by enormous opportunities awaiting further exploitation.

The population of this island is today 53 millions and has been increasing at the rate of 0·4% per year, compared with 1·2%, 0·9%, and 1·7% respectively for Germany, France, and USA. One thing is certain and that is that we could feed, clothe, and house 50% more people assuming that these people contained the normal percentage of producers for home consumption and export. We need not worry if the attraction of our standard of life, our high 'eudemony' as I have called it in another place,[2] brings in many immigrants. A rise in population brings at least an equivalent rise in demand for steel. It would bring here the prosperity of a growing economy, as it has recently done in Germany. Curiously enough we take numerous steps to restrict immigration and do little to encourage a rising population.



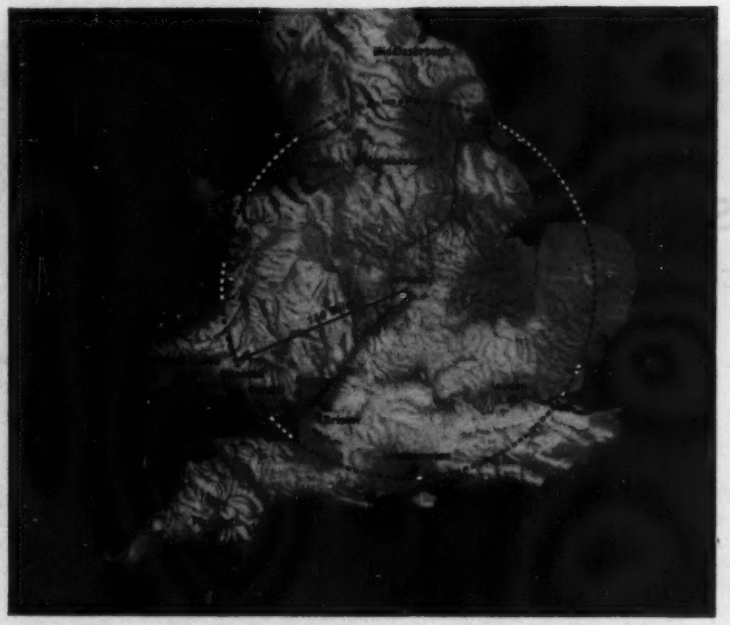
2 *Britain's position at the centre of the populated land areas of the globe (azimuthal equidistant projection about London as a centre)*

Energy sources are vital to the future of any steel industry and here the optimism in my previous crystal gazing needs modification. Something has gone wrong or stayed wrong with our coal industry. The pithead cost of our plentiful coking coal has increased nearly six-fold since pre-war, whereas the American cost has hardly doubled and is now less than three-quarters of ours. It is cheaper today to bring coal from America to Scotland and parts of South Wales than to bring it from local sources. The American miners' wage level is three times ours at the present exchange rate but the productivity of these miners is seven times higher. It is true that American coal seams favour a high productivity but not by a factor of seven. Mechanization is proceeding in British mines at a commendable rate but it still has a long way to go.

One of the biggest obstacles to the raising of British productivity is the traditional market for large coal, mostly for domestic fires. Despite the fact that the efficiency of burning such coal is very low and that its use is gradually being discouraged by the creation of smokeless zones and by railway conversion, the Coal Board[3] designs and operates its new mining methods to avoid breaking up the coal, with a consequent extra cost. This situation, coupled with the fact that the Board is not permitted for political reasons to charge an economic price for this coal, constitutes a serious example of backward looking.

This tradition of large coal is the cause of a second serious cost factor. The coal industry adopted many years ago a load gauge much lower than that of the railways, restrictive as the latter is. As a result it limits the acceptance of high-capacity wagons on our railways, thus giving us the highest ton-mile cost of any railway in Europe. In the large railway modernization programme, coal transport productivity has actually gone down compared with the standards of one of the pre-nationalization railways, the LNER.

The energy picture is not all black. For one thing the nearly six-fold rise in our coking coal prices over the last 25 years has been partly offset by a fall of 45% in our national average coke rate, now 16·5 cwt/ton of iron (or 18·3 cwt if we include the breeze for sintering). The technological changes which have led to this will continue and should reduce the coke rate to about 15 cwt and the development of tuyere injection of oil



1 *Main ports for Britain's manufacturing areas. Coventry is about as far from the sea as it is possible to be, yet it has two ports within 90 miles and six more within 110 miles*

encourage individual specialization, an essential to high productivity, because of the short distances and easy terrain over which people and things can be transported. Manufacturers nowadays depend on each other to an extent unknown a generation or so ago and this interdependence is increasing as technology advances.

The fifth advantage is the central location of this country on the globe. The world has need for a centre to carry out certain commercial and financial operations. It also needs a centre of trade in commodities, such as metals, diamonds, and furs in order to introduce stability and quick response into the world's supply and demand situation. It needs a centre where the maximum amount of scientific and other knowledge and information can be collected and made available. It needs a centre to collect together and develop the best ideas of social and political organization arising in Europe, America, or Asia. Yet at the same time this centre must not be part of America, Continental Europe, or Asia if it is to be impartial.

The position of Great Britain is outstandingly good in this respect. It lies effectively at the centre of the populated land areas of the globe as is shown in Fig.2. This map is an 'azimuthal equidistant projection' about London as a centre and shows the distance from London along the shortest route, the 'great circle route', to any point on the hemisphere. It is perhaps easier to visualize this map if it is said that it is very similar to the view of the world that a space traveller would have from a point a few thousand miles above London. It is to be noted from the map that, with the advent of air travel, we have become remarkably well placed, in that we are within non-stop flying distance of the capitals of the countries representing over 90% of the world's population. It is surprising to note that even Tokyo and Cape Town are in our hemisphere.

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THE COMMONWEALTH

For some centuries now our countrymen have left this country through our ports to develop what has now become the Commonwealth. Membership of this group gives this country a unique advantage over others. It is not one of the five indigenous advantages but it arises therefrom. Unlike the other five it could fade away, but like them it could be exploited much more than it has been.

But traditions die hard. For generations we have looked upon the 'Empire' as a source of extra food and of raw materials and a market for our consumer goods. Now the realization is spreading that there are people living on these lands with aspirations not unlike our own, and that their legitimate desires to raise their own standards of living can only be met by themselves manufacturing a substantial part of their needs. There is a slowly growing acceptance of the universal law of economics which says that no country can in the long run import more or less than it exports; every country's payments must balance, not just our own. Unless a country is especially rich in a commodity that the world wants, such as oil or copper, its imports would be low. If its standard of living were dependent upon imports, unsupported by free aid, it too would be low. No self-respecting country will accept this situation for long and indeed, history shows that most countries have an internal growth of production faster than the growth of their imports. The short-sighted attitude that other country's balances of payments are their problem and not ours is a far too common result of our obsession about our own. Depending as we do on trade, we will not get very far without recognizing our fellow traders' problems.

But the Commonwealth is not important just because its people need our help and because we need its food and raw materials. Without it this island country would sink from being one of the great three, nearly to the level where our population, ninth in order of size, would put us. The Commonwealth links of trust, based on common basic social beliefs and a common language, on mutual knowledge and respect, give us a network of contacts which have enabled us to exploit our fifth advantage and to maintain our position at the centre of the world. The *Economist* has likened the network to a 'bunch of keys' giving us a closer understanding with and hence access to practically every race and indeed nation on this globe: Canada, a key to the USA, Nigeria, etc. to the rest of Africa, Hong Kong to China, and so on. As transport and communications advance technologically, the value to the world as a whole and therefore to this island's inhabitants of this network and of its consequences will continue to increase. But we must not take these links of the Commonwealth for granted.

One of the major ways of maintaining these links is through inter-migration for educational purposes or for permanent employment, and the Government's policy in encouraging this for both purposes has been very successful. We now have the largest number of students from overseas of any country in the world and two-thirds of these come from the Commonwealth. There is a strong flow of permanent migrants to the Commonwealth and a healthy flow in the reverse direction. The weakest aspect is that very few of our students study in overseas centres and hardly any at all in Commonwealth countries.

The steel industry has been advancing its internal educational system and has been extending this to include students from overseas, a large number of whom come from India.

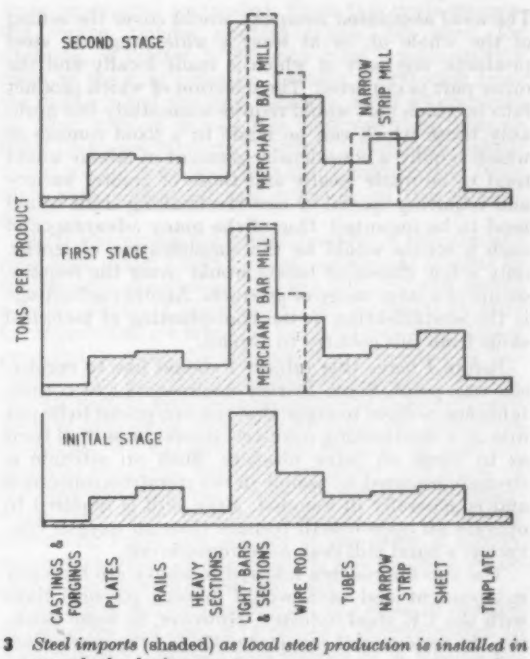
The Government's help for education and migration between parts of the Commonwealth, large as it is, is small compared with the support that it gives to Commonwealth trade. Some industries have responded to this and set up subsidiaries or related companies in many parts of the world. This is particularly true of the chemical industry but the steel industry has been too busy expanding to meet home requirements to find much time and money to invest in the Commonwealth or in other countries abroad. There are large areas where steel developments are taking or will take place, such as Western Canada, Pakistan, and Africa, but these, with few exceptions, have been left to other

European or to American companies to exploit. The magnificent efforts in India of the British steelplant makers, with the help of a number of steelmakers, can be repeated now that steel capacity is overtaking demand at home.

In considering investment by the steel industry in the Commonwealth or in other countries abroad, there are two main approaches, one from the local resources of raw materials including fuel, the other from the local market. From the first, one soon meets an obstacle, the very high capital costs of the coke-oven blast-furnace assembly, costs which only begin to look reasonable when you get well over the thousand tons a day unit, and have a good degree of integration with other units. Technical developments have regularly claimed to alter this situation; a new ironmaking process is announced nearly every few months and it is likely that one or other of these will find a niche in the not too distant future. For example, in an area of cheap electric power and good iron ore, such as Quebec–Labrador, the production of a low-carbon pure iron in the easily shippable pellet form would provide an excellent feed for electric furnaces making high-quality steel. Similarly the reduction of ore, say in Trinidad or in a non-Commonwealth country such as North Africa, by a cheap local natural gas or oil, often one-fifth to one-tenth the cost of a therm of British coke, would produce a shippable sponge iron. The saving in the cost of shipping either of these products, which weigh less than two-thirds of the original ore, would amount to between 10*s*. and 20*s*. per ton of iron and would go a long way to compensate for the loss of the sensible heat in the liquid iron. The very low energy costs in certain iron ore localities abroad makes it likely that one or other of these developments will soon find a place in the supply line to the European steel industry; that is, we will import metallic iron as well as ore. Our industry should not only be at the receiving end, but should be actively involved in the developments themselves if we are to get the maximum advantage.

The other approach, from the local markets, has already been followed to some extent. Newly developing countries represent a large potential market for steel products of an enormous variety, light and heavy structurals, rails, ferro-concrete rods, galvanized sheeting, wire for fences, nuts and bolts, etc. The demand in any one country is limited only by its ability to export raw materials or other goods to pay for such steel products among the many other necessary imports. Newly developing countries do not want to make steel only for prestige purposes but rather to release them from the restrictions of their balance of payments which holds their standard of living down.

Here, too, the size of a steelworks necessary to achieve a reasonably low capital cost per ton is a serious obstacle; the optimum size of today's standard units are five- to ten-fold larger than pre-war. However, recent developments are improving the economics of some of the smaller units and thus are coming to the aid of the newly developing countries. Electric melting furnaces, continuous casting plants, and simpler rolling mills now make economic a unit steelworks of a few hundred thousand tons per year, providing it concentrates on a narrow range of products. Such a works would partly be based on local scrap but would also import 'semis'.



3 *Steel imports* (shaded) *as local steel production is installed in a newly developing country*

The probable course of development of steel production in a new country is illustrated in Fig.3. In this very over-simplified picture the hundreds of different steel products are grouped and the tons of steel consumed plotted vertically for each group.

The lower histogram shows the country with no local production and with its consumption of steel and hence its standard of living restricted by the foreign exchange which it can earn from exports. Its first move upwards would be to persuade foreign investors or aid to install a merchant bar mill. Such a mill would produce quite a wide range of products the availability of which would stimulate consumption not only of these products but of the other steel products which have to be imported. For example, if it made light structurals it would stimulate a demand for galvanized sheets and heavier structurals. In the first instance, at least, it might have to be fed with imported billets but these would be much cheaper than the finished steel products they would supplant. In due course, the mill could be based on local scrap put through an electric furnace and a continuous casting plant.

At a later stage another mill is set up, possibly this time a narrow or medium strip and skelp mill coupled with a small tube-making plant. As is shown in the upper part of the figure this would again raise the demand for other steel products. The three histograms illustrate how a rise in standard of living can be obtained without a change in the total volume of steel imports.

This diagram is of course, very hypothetical, but is included to emphasize the point that the market in newly developing countries for British steel need not be reduced (but might even be increased) by the setting up of a local steel mill *provided* first that this mill is set up in association with a British steelmaker, and secondly, of course, that our prices are competitive.

REVIEW

C. J. Smithells

'The determination of gases in metals'

This is a report of a symposium held in London on 3–4 May 1960. It comprises a foreword by Mr R. C. Chirnside, President of the Society for Analytical Chemistry, and 15 papers and the discussions on them. The symposium was organized by the Society for Analytical Chemistry in conjunction with The Iron and Steel Institute and The Institute of Metals. It was organized in order to bring together chemists and physicists working in a wide range of industries but who are all interested in the development of better analytical methods of determination of gases in metals. This is the first time that such a conference has been held in this country and the large number of papers presented not only by British authors but also by authors from overseas indicates how the significance of gases in metals has come to be realized during the last 15 years. Before the last war the importance of the effects of gases in metals had received very limited recognition, and rapid methods of analysis suitable for control purposes had scarcely been developed. The Society for Analytical Chemistry has done a valuable service to the metallurgical industry in organizing this symposium and in bringing together in one volume so much specialized knowledge in this important field.

Somewhat naturally, the majority of the papers deal only with hydrogen, nitrogen, and oxygen, and again the majority relate to ferrous alloys, although some of the newer metals in which the effects of gases are particularly important are also considered. The classical methods for the determination of gases in metals were almost entirely restricted to vacuum extraction or vacuum fusion methods, and these methods still form a large part of the papers under discussion. A pioneer in this field was Mr H. A. Sloman of the National Physical Laboratory who acted as Chairman of the symposium.

The papers may be divided into three groups: review papers by W. T. Elwell, J. D. Hobson, and R. Eborall on the determination of oxygen, nitrogen, and hydrogen respectively: a second group of papers in which the more conventional methods of determination are described in detail and recent improvements in technique are emphasized: a third group which covers the newer physical methods based on spectroscopy, radioactivation and isotope dilution analysis, carrier gas techniques, X-ray diffraction and X-ray fluorescence analysis, and measurements of internal friction.

The three review papers, each about 25 pages in length, give an excellent summary of the methods at present in use for determining the three important gases, hydrogen, nitrogen, and oxygen. In each case a very full bibliography is given, and these papers will be valuable for reference purposes. Papers relating to the more conventional analytical methods are mainly of special application. J. V. Dawson and L. W. L. Smith describe the determination of hydrogen in cast iron by vacuum extraction, J. E. Still describes the application of vacuum fusion techniques to the determination of gases in Ti, Zr, Mo, and Be for research purposes, and the methods are not intended for routine analysis. The same group of metals, and particularly beryllium, are the subject of A. Parker's paper on semi-micro vacuum-fusion methods. T. P. King's paper discusses in detail alternative methods of sampling steel for oxygen and nitrogen determinations and provides a valuable review of the alternative methods in use. A paper by H. F. Beeghly describes solution methods for determining nitrides in steel and discusses the effects of nitrogen and nitrides on properties.

The third group of papers, namely the application of newer physical methods to the determination of gases, will probably be of more general interest, particularly to those who are already using the conventional methods for routine purposes. Some of these methods have general application and some are being developed in connexion with special requirements and in some cases are able to give extremely rapid results. Many of these are still in an early stage of development and their reliability remains to be proved, particularly where the results do not accord with those obtained by conventional methods. Carrier gas techniques are described by C. E. A. Shanahan and by F. R. Coe and N. Jenkins. In the carrier gas method a stream of inactive (or in some cases reactive) gas is allowed to pass over the heated metal as an alternative to using vacuum extraction. This provides a very much more rapid method of analysis and, using argon as the carrier, as many as 180 samples for oxygen determination can be handled in 24 h. Coe and Jenkins have made use of a thermal conductivity cell with a carrier gas technique in determining hydrogen in steel. Another new method has been applied by R. F. Coleman to the determination of oxygen in beryllium by activation analysis. In this method the sample is irradiated by neutrons or gamma radiation when the gases produce unstable isotopes with characteristic decay rates, and the analysis is based on measurement of their activity.

X-ray emission analysis has previously been applied successfully to metals and T. Mulvey describes the application of this method to the determination of hydrogen, nitrogen, and oxygen. This is still of course in an experimental stage. A new method of applying emission spectrography is described by V. A. Fassel. The sample is melted in a dc carbon arc discharge in pure argon. This not only results in the extraction of the gas but the discharge provides the necessary emission. It has been applied to the determination of oxygen, nitrogen, and hydrogen in steels and the transition metals, and with two operators, 50 analyses per day are possible.

Isotope dilution has been applied by M. L. Pearce and C. R. Masson to the determination of oxygen and nitrogen in iron and steel. The principle of the method is that ^{18}O is diluted with the normal ^{16}O during extraction under vacuum fusion. The method gives appreciably higher results than are normally obtained with vacuum fusion and, although the authors believe their method is more reliable, it obviously requires further investigation.

The last of the newer methods is the application of damping capacity measurements to the determination of nitrogen in alpha iron. This is described in a paper by G. M. Leak. The large number of factors which enter into the accurate determination of damping capacity make it unlikely that this will ever be a practically useful method of analysis, although it may give useful information in some cases as a research tool.

It is particularly interesting to note that this symposium brought together people working in both ferrous and non-ferrous fields and those interested in a wide range of analytical methods. This alone would have justified the holding of the symposium. Publication of all these papers as a single volume will be widely welcomed and will fill a gap which has existed for a long time in metallurgical literature.

STAL *in English*

Number 1 (January) of the 1961 series of the cover-to-cover translation of the Russian journal *Stal'* has been published, and nos.2 and 3 will follow shortly. Principal contents of no.3 are given below. Full details of subscriptions to *Stal in English* are available from the Secretary of The Iron and Steel Institute.

IRONMAKING

Conditions for removal of sulphur in sintering process

Temperature and composition of iron in destroyed section of blast-furnace hearth bottom

Analysis of heat-exchange processes in blast-furnaces

Utilization of nickel when melting pig iron from natural alloy ores

STEELMAKING

Mastering operation of 500-ton open-hearth furnace, fired by coke-oven gas and fuel oil

Investigation of melting of charge in open-hearth furnaces when using various methods of oxygen injection

Use of high-grade ferroaluminium for deoxidation of killed steel

Floating hot nozzle with ceramic ring

Temperature conditions of heats when converting phosphorus iron

ROLLING AND TUBE PRODUCTION

Mastering rolling of lightweight sections of low-alloy steels

Efficiency of universal stands of plate-rolling mills

Reasons for bulging of ingots and slabs

Performance of double-stand reducing mill with individual drive

Improvement of roll-pass designs and of mandrels for piercing of large ingots

METALWORKING AND HEAT-TREATMENT

High-chromium steels with titanium and nitrogen instead of 1Kh18N9 and 1Kh18N9T steels

Influence of composition of chrome–aluminium steels on extent of their spotted liquation

Influence of slaty structure on properties of carbon steel

Reasons for formation of blisters on cold-rolled sheets of 08Kp steel

Influence of austenite-forming constituents on properties of Kh28 steel

HEAT TECHNOLOGY

Supplying soaking pits with hot ingots

POWER AND PLANT

Cleaning of gases from top-blown oxygen converters

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For some centuries now our countrymen have left this country through our ports to develop what has now become the Commonwealth. Membership of this group gives this country a unique advantage over others. It is not one of the five indigenous advantages but it arises therefrom. Unlike the other five it could fade away, but like them it could be exploited much more than it has been.

But traditions die hard. For generations we have looked upon the 'Empire' as a source of extra food and of raw materials and a market for our consumer goods. Now the realization is spreading that there are people living on these lands with aspirations not unlike our own, and that their legitimate desires to raise their own standards of living can only be met by themselves manufacturing a substantial part of their needs. There is a slowly growing acceptance of the universal law of economics which says that no country can in the long run import more or less than it exports; every country's payments must balance, not just our own. Unless a country is especially rich in a commodity that the world wants, such as oil or copper, its imports would be low. If its standard of living were dependent upon imports, unsupported by free aid, it too would be low. No self-respecting country will accept this situation for long and indeed, history shows that most countries have an internal growth of production faster than the growth of their imports. The short-sighted attitude that other country's balances of payments are their problem and not ours is a far too common result of our obsession about our own. Depending as we do on trade, we will not get very far without recognizing our fellow traders' problems.

But the Commonwealth is not important just because its people need our help and because we need its food and raw materials. Without it this island country would sink from being one of the great three, nearly to the level where our population, ninth in order of size, would put us. The Commonwealth links of trust, based on common basic social beliefs and a common language, on mutual knowledge and respect, give us a network of contacts which have enabled us to exploit our fifth advantage and to maintain our position at the centre of the world. The *Economist* has likened the network to a 'bunch of keys' giving us a closer understanding with and hence access to practically every race and indeed nation on this globe: Canada, a key to the USA, Nigeria, etc. to the rest of Africa, Hong Kong to China, and so on. As transport and communications advance technologically, the value to the world as a whole and therefore to this island's inhabitants of this network and of its consequences will continue to increase. But we must not take these links of the Commonwealth for granted.

One of the major ways of maintaining these links is through inter-migration for educational purposes or for permanent employment, and the Government's policy in encouraging this for both purposes has been very successful. We now have the largest number of students from overseas of any country in the world and two-thirds of these come from the Commonwealth. There is a strong flow of permanent migrants to the Commonwealth and a healthy flow in the reverse direction. The weakest aspect is that very few of our students study in overseas centres and hardly any at all in Commonwealth countries.

The steel industry has been advancing its internal educational system and has been extending this to include students from overseas, a large number of whom come from India.

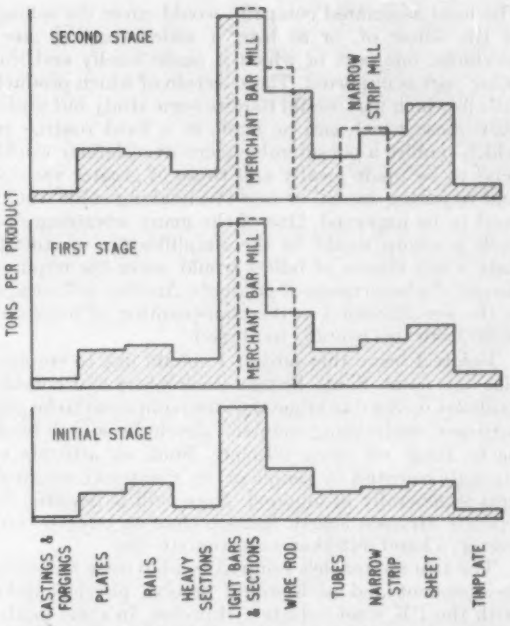
The Government's help for education and migration between parts of the Commonwealth, large as it is, is small compared with the support that it gives to Commonwealth trade. Some industries have responded to this and set up subsidiaries or related companies in many parts of the world. This is particularly true of the chemical industry but the steel industry has been too busy expanding to meet home requirements to find much time and money to invest in the Commonwealth or in other countries abroad. There are large areas where steel developments are taking or will take place, such as Western Canada, Pakistan, and Africa, but these, with few exceptions, have been left to other

European or to American companies to exploit. The magnificent efforts in India of the British steelplant makers, with the help of a number of steelmakers, can be repeated now that steel capacity is overtaking demand at home.

In considering investment by the steel industry in the Commonwealth or in other countries abroad, there are two main approaches, one from the local resources of raw materials including fuel, the other from the local market. From the first, one soon meets an obstacle, the very high capital costs of the coke-oven blast-furnace assembly, costs which only begin to look reasonable when you get well over the thousand tons a day unit, and have a good degree of integration with other units. Technical developments have regularly claimed to alter this situation; a new ironmaking process is announced nearly every few months and it is likely that one or other of these will find a niche in the not too distant future. For example, in an area of cheap electric power and good iron ore, such as Quebec–Labrador, the production of a low-carbon pure iron in the easily shippable pellet form would provide an excellent feed for electric furnaces making high-quality steel. Similarly the reduction of ore, say in Trinidad or in a non-Commonwealth country such as North Africa, by a cheap local natural gas or oil, often one-fifth to one-tenth the cost of a therm of British coke, would produce a shippable sponge iron. The saving in the cost of shipping either of these products, which weigh less than two-thirds of the original ore, would amount to between 10*s*. and 20*s*. per ton of iron and would go a long way to compensate for the loss of the sensible heat in the liquid iron. The very low energy costs in certain iron ore localities abroad makes it likely that one or other of these developments will soon find a place in the supply line to the European steel industry; that is, we will import metallic iron as well as ore. Our industry should not only be at the receiving end, but should be actively involved in the developments themselves if we are to get the maximum advantage.

The other approach, from the local markets, has already been followed to some extent. Newly developing countries represent a large potential market for steel products of an enormous variety, light and heavy structurals, rails, ferro-concrete rods, galvanized sheeting, wire for fences, nuts and bolts, etc. The demand in any one country is limited only by its ability to export raw materials or other goods to pay for such steel products among the many other necessary imports. Newly developing countries do not want to make steel only for prestige purposes but rather to release them from the restrictions of their balance of payments which holds their standard of living down.

Here, too, the size of a steelworks necessary to achieve a reasonably low capital cost per ton is a serious obstacle; the optimum size of today's standard units are five- to ten-fold larger than pre-war. However, recent developments are improving the economics of some of the smaller units and thus are coming to the aid of the newly developing countries. Electric melting furnaces, continuous casting plants, and simpler rolling mills now make economic a unit steelworks of a few hundred thousand tons per year, providing it concentrates on a narrow range of products. Such a works would partly be based on local scrap but would also import 'semis'.



3 *Steel imports* (shaded) *as local steel production is installed in a newly developing country*

The probable course of development of steel production in a new country is illustrated in Fig.3. In this very over-simplified picture the hundreds of different steel products are grouped and the tons of steel consumed plotted vertically for each group.

The lower histogram shows the country with no local production and with its consumption of steel and hence its standard of living restricted by the foreign exchange which it can earn from exports. Its first move upwards would be to persuade foreign investors or aid to install a merchant bar mill. Such a mill would produce quite a wide range of products the availability of which would stimulate consumption not only of these products but of the other steel products which have to be imported. For example, if it made light structurals it would stimulate a demand for galvanized sheets and heavier structurals. In the first instance, at least, it might have to be fed with imported billets but these would be much cheaper than the finished steel products they would supplant. In due course, the mill could be based on local scrap put through an electric furnace and a continuous casting plant.

At a later stage another mill is set up, possibly this time a narrow or medium strip and skelp mill coupled with a small tube-making plant. As is shown in the upper part of the figure this would again raise the demand for other steel products. The three histograms illustrate how a rise in standard of living can be obtained without a change in the total volume of steel imports.

This diagram is of course, very hypothetical, but is included to emphasize the point that the market in newly developing countries for British steel need not be reduced (but might even be increased) by the setting up of a local steel mill *provided* first that this mill is set up in association with a British steelmaker, and secondly, of course, that our prices are competitive.

The local associated company would cover the selling of the whole of, or at least a wide range of, steel products, one part of which is made locally and the other part is imported. The selection of which product falls in which part would require some study but probably those which can be made to a fixed routine or which require a considerable element of labour would tend to be made locally and those of greater variety and requiring special or new steelmaking skills would tend to be imported. One of the many advantages of such a set-up would be the simplification of stocks; only a few classes of billets would cover the requirements of a large range of products. Another advantage is the simplification in the transplanting of technical skills from this country to abroad.

Before I leave this subject I should like to emphasize one point. Some British steelmakers and consultants are inclined to argue that the equipment to be put into new steelmaking countries should be so well tried as to verge on being obsolete. Such an attitude is strongly resented by people in the countries concerned and is generally ill-founded. More skill is required to operate an open-hearth furnace than an oxygen converter, a hand mill than an automatic one.

The two approaches referred to above are basically independent and each would involve physical links with the UK steel industry. However, in some localities the resources of raw materials and the market are sufficiently close together to justify integration of the primary and secondary stages of production. An integrated development in such a locality would still be of substantial concern to our industry. For one thing the integration would not be complete and would cover only a range of products. But there is another reason.

CAPITAL EQUIPMENT FOR EXPORT AND FOR HOME USE

This picture regarding steel applies to many industries; British-associated factories in newly developing countries are important if our imports to those countries are to be secure. More important still is the market that is thus provided for the makers of capital equipment The biggest opportunity that this country has is to become the principal maker of capital equipment for export to the world. We have everything in our favour, except tradition. We have low-cost steel and other necessary raw materials. We have perhaps the most comprehensive range of users of capital equipment to be found anywhere and much of their equipment is of modern and progressive design. Through our ports and ships we have, or could have, access by cheap transport to any part of the world. The development of air freight coupled with our central position on the globe means that spares need not be carried at local works because they can be readily flown out. We have an exchange rate which gives us a wage rate one-third that of our biggest competitor, the USA. This advantage is likely to remain for some time in view of the commitments of that country's government to keep up the exchange value of the dollar. We could produce a big share of the world's carpet-making machinery, bottle and can-making machinery, machine tools, instruments, etc., thousands of highly specialized types of equipment that can best only be produced centrally and incorporating the latest scientific and engineering knowledge so easily available to us in this country.

The export of capital equipment is, of course, only part of a general national policy. Any already affluent country wishing to raise or maintain the standard of living of its people must try preferentially to export those goods which have the highest added value *per man-hour of labour content*, that is, of its people's work. It is surprising how frequently people wrongly shorten this criterion to goods of 'highest value'. Several groups of our goods meet this criterion. Machinery is one. Special consumer goods is another. Obviously high productivity using low-cost materials is an essential part of the criterion.

In some fields of machinery, manufacturers have responded to this opportunity but on the whole we continue to lose ground, particularly to Germany. While we are increasing our machinery exports at what looks to be a substantial rate the rest of the world is increasing still faster; we are holding a decreasing proportion of world trade in machinery.[6] Much of this we can blame on certain traditions; traditions so firmly ingrained that daily exhortations by government and far-seeing industrial officials make little impact; traditions born in the period when we had accumulated so much foreign investment we could and generally did buy much of our equipment abroad; traditions that once a man has learned one trade he must resist learning another. If we can learn to discriminate between useful traditions and restrictive ones we can grasp this opportunity.

At the present time the larger part, about two-thirds, of the steel produced in UK remains at home either as consumer or capital goods. The steel content of consumer goods tends to fall and therefore the bigger opportunities for increased use of steel at home are in capital investment. Extensive as this has been in recent years, there are many fields in which much remains to be done. The exploitation of our fourth advantage is a case in point. Anyone who has studied internal transport becomes imbued with the enormous magnitude of the task in front of us and the benefits that will follow from action. As long as the inhabitants of this island were not acquainted with modern roads, underpasses, and railway equipment the pressure to get them was weak and ineffective. Just as queuing became an accepted part of life, traffic delays have been looked upon as inevitable. But now we have samples of modern transport and the more these samples multiply the more intolerant will people become of the inefficient.

A similarly encouraging future for the demand for steel lies with the building trade. The situation here is rather like the roads. As long as streets such as Shaftesbury Avenue and thousands of others are uniformly old, dirty, and depressing, the minds of the people concerned become attuned. But the war made holes which are now being filled with new buildings. A situation with new, efficient, and (sometimes) beautiful buildings mixed with the old and decrepit is unstable and the pressure to replace the old will grow.

We will get our beautiful cities, our efficient roads, our Victoria Line, our Channel Tunnel, our economic farm produce marketing and distributing organizations, our decimal systems, as soon as the resources in manpower and materials permit. The second we now have; steel joins the other primary materials in being in good supply. We need only the manpower and the will.

MANPOWER THE SOLUTION

How are we to get the manpower? Immigration would help but it is too slow and could not make the impact it has in Germany. More investment by British manufacturers in countries with a plentiful supply of labour, such as in parts of the Commonwealth, would enable that labour to make a bigger contribution to our problems. But an increase in productivity is our main hope. Big as the improvements have been in the last ten years or so, they have hardly kept pace with the expanding possibilities. For example, although each man in the steel industry makes on the average 90 tons of steel per year compared with 65 tons ten years ago, with more modern equipment incorporating known technical improvements and a certain amount of rationalization, today's figure could be doubled. Similarly in agriculture, productivity has doubled in the last 20 years, but a further 50% increase is possible. Hundreds of thousands of men and women in this country spend their time less productively than need be. They cannot be released from this position because of a rigidity of thought and because their principal asset, their skill at a particular job, would be partly lost. Also there are powerful psychological forces against the movement of labour, fostered mainly by the complaint-loving press; instead of men being 'released' to do a more useful job, they are made 'redundant' or 'sacked'. Much study and effort has been put into this problem of flexibility but without much effect; nor is there likely to be much effect until men will look forward. This they will not do so long as they by habit look back for their security.

Much lip service is paid to higher productivity but action is very slow and in many industries we are losing ground.[7] The Government preaches high productivity but applies taxes in a way to discourage it. The management problems involved in a change frighten many managers. The word is not to everyone a 'nice' word and to many more it is incomprehensible; on several occasions I have heard it said that 'It is more production we need, not more productivity!'

We are in a vicious circle; the shortage of men caused by our low productivity prevents us building enough more productive equipment. From this circle we cannot escape without positive action. We need, for example, to release 50000 men from low-productive parts of the coal industry, another 25000 each from the railways and the steel industry, all of which could be done without serious loss, and use these men to build high-productivity capital equipment which would release more men from many industries to build more such equipment and speed us on this upward road.

On re-examining the overall position of this country after four years, I find nothing substantial to alter in the previous conclusion. This is a rich and well placed country, a land of opportunity. The prospects for steel for exports and for home use are good providing we are prepared to grasp the opportunities presented by this country and by the Commonwealth associated with it. We will need to become more flexible in movement and forward-minded in thought and scrap our restrictive traditions. We will need to stop wasting our basically plentiful resources, our coal, our water, our ports, or our once plentiful man-power. We will have to appreciate more fully Britain's potential in the rapidly advancing world and get out of the habit of merely patting ourselves on the back for the progress we do make, magnificent as that has been.

Our job as technical people is quite clear, to develop in ourselves and inspire in others a determination to overcome the obstacles that restrict us in making the best of our natural advantages.

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REVIEW

C. J. Smithells

'The determination of gases in metals'

This is a report of a symposium held in London on 3–4 May 1960. It comprises a foreword by Mr R. C. Chirnside, President of the Society for Analytical Chemistry, and 15 papers and the discussions on them. The symposium was organized by the Society for Analytical Chemistry in conjunction with The Iron and Steel Institute and The Institute of Metals. It was organized in order to bring together chemists and physicists working in a wide range of industries but who are all interested in the development of better analytical methods of determination of gases in metals. This is the first time that such a conference has been held in this country and the large number of papers presented not only by British authors but also by authors from overseas indicates how the significance of gases in metals has come to be realized during the last 15 years. Before the last war the importance of the effects of gases in metals had received very limited recognition, and rapid methods of analysis suitable for control purposes had scarcely been developed. The Society for Analytical Chemistry has done a valuable service to the metallurgical industry in organizing this symposium and in bringing together in one volume so much specialized knowledge in this important field.

Somewhat naturally, the majority of the papers deal only with hydrogen, nitrogen, and oxygen, and again the majority relate to ferrous alloys, although some of the newer metals in which the effects of gases are particularly important are also considered. The classical methods for the determination of gases in metals were almost entirely restricted to vacuum extraction or vacuum fusion methods, and these methods still form a large part of the papers under discussion. A pioneer in this field was Mr H. A. Sloman of the National Physical Laboratory who acted as Chairman of the symposium.

The papers may be divided into three groups: review papers by W. T. Elwell, J. D. Hobson, and R. Eborall on the determination of oxygen, nitrogen, and hydrogen respectively: a second group of papers in which the more conventional methods of determination are described in detail and recent improvements in technique are emphasized: a third group which covers the newer physical methods based on spectroscopy, radioactivation and isotope dilution analysis, carrier gas techniques, X-ray diffraction and X-ray fluorescence analysis, and measurements of internal friction.

The three review papers, each about 25 pages in length, give an excellent summary of the methods at present in use for determining the three important gases, hydrogen, nitrogen, and oxygen. In each case a very full bibliography is given, and these papers will be valuable for reference purposes. Papers relating to the more conventional analytical methods are mainly of special application. J. V. Dawson and L. W. L. Smith describe the determination of hydrogen in cast iron by vacuum extraction, J. E. Still describes the application of vacuum fusion techniques to the determination of gases in Ti, Zr, Mo, and Be for research purposes, and the methods are not intended for routine analysis. The same group of metals, and particularly beryllium, are the subject of A. Parker's paper on semi-micro vacuum-fusion methods. T. P. King's paper discusses in detail alternative methods of sampling steel for oxygen and nitrogen determinations and provides a valuable review of the alternative methods in use. A paper by H. F. Beeghly describes solution methods for determining nitrides in steel and discusses the effects of nitrogen and nitrides on properties.

The third group of papers, namely the application of newer physical methods to the determination of gases, will probably be of more general interest, particularly to those who are already using the conventional methods for routine purposes. Some of these methods have general application and some are being developed in connexion with special requirements and in some cases are able to give extremely rapid results. Many of these are still in an early stage of development and their reliability remains to be proved, particularly where the results do not accord with those obtained by conventional methods. Carrier gas techniques are described by C. E. A. Shanahan and by F. R. Coe and N. Jenkins. In the carrier gas method a stream of inactive (or in some cases reactive) gas is allowed to pass over the heated metal as an alternative to using vacuum extraction. This provides a very much more rapid method of analysis and, using argon as the carrier, as many as 180 samples for oxygen determination can be handled in 24 h. Coe and Jenkins have made use of a thermal conductivity cell with a carrier gas technique in determining hydrogen in steel. Another new method has been applied by R. F. Coleman to the determination of oxygen in beryllium by activation analysis. In this method the sample is irradiated by neutrons or gamma radiation when the gases produce unstable isotopes with characteristic decay rates, and the analysis is based on measurement of their activity.

X-ray emission analysis has previously been applied successfully to metals and T. Mulvey describes the application of this method to the determination of hydrogen, nitrogen, and oxygen. This is still of course in an experimental stage. A new method of applying emission spectrography is described by V. A. Fassel. The sample is melted in a dc carbon arc discharge in pure argon. This not only results in the extraction of the gas but the discharge provides the necessary emission. It has been applied to the determination of oxygen, nitrogen, and hydrogen in steels and the transition metals, and with two operators, 50 analyses per day are possible.

Isotope dilution has been applied by M. L. Pearce and C. R. Masson to the determination of oxygen and nitrogen in iron and steel. The principle of the method is that ^{18}O is diluted with the normal ^{16}O during extraction under vacuum fusion. The method gives appreciably higher results than are normally obtained with vacuum fusion and, although the authors believe their method is more reliable, it obviously requires further investigation.

The last of the newer methods is the application of damping capacity measurements to the determination of nitrogen in alpha iron. This is described in a paper by G. M. Leak. The large number of factors which enter into the accurate determination of damping capacity make it unlikely that this will ever be a practically useful method of analysis, although it may give useful information in some cases as a research tool.

It is particularly interesting to note that this symposium brought together people working in both ferrous and non-ferrous fields and those interested in a wide range of analytical methods. This alone would have justified the holding of the symposium. Publication of all these papers as a single volume will be widely welcomed and will fill a gap which has existed for a long time in metallurgical literature.

STAL *in English*

Number 1 (January) of the 1961 series of the cover-to-cover translation of the Russian journal *Stal'* has been published, and nos.2 and 3 will follow shortly. Principal contents of no.3 are given below. Full details of subscriptions to *Stal in English* are available from the Secretary of The Iron and Steel Institute.

IRONMAKING

Conditions for removal of sulphur in sintering process

Temperature and composition of iron in destroyed section of blast-furnace hearth bottom

Analysis of heat-exchange processes in blast-furnaces

Utilization of nickel when melting pig iron from natural alloy ores

STEELMAKING

Mastering operation of 500-ton open-hearth furnace, fired by coke-oven gas and fuel oil

Investigation of melting of charge in open-hearth furnaces when using various methods of oxygen injection

Use of high-grade ferroaluminium for dexoidation of killed steel

Floating hot nozzle with ceramic ring

Temperature conditions of heats when converting phosphorus iron

ROLLING AND TUBE PRODUCTION

Mastering rolling of lightweight sections of low-alloy steels

Efficiency of universal stands of plate-rolling mills

Reasons for bulging of ingots and slabs

Performance of double-stand reducing mill with individual drive

Improvement of roll-pass designs and of mandrels for piercing of large ingots

METALWORKING AND HEAT-TREATMENT

High-chromium steels with titanium and nitrogen instead of 1Kh18N9 and 1Kh18N9T steels

Influence of composition of chrome–aluminium steels on extent of their spotted liquation

Influence of slaty structure on properties of carbon steel

Reasons for formation of blisters on cold-rolled sheets of 08Kp steel

Influence of austenite-forming constituents on properties of Kh28 steel

HEAT TECHNOLOGY

Supplying soaking pits with hot ingots

POWER AND PLANT

Cleaning of gases from top-blown oxygen converters

Reconstitution of the light section mill at Round Oak Steel Works Ltd

W. S. Walker, Ph.D., M.Sc.(Tech.), J. F. Whitfield, B.Sc., M.I.Mech.E., and G. A. V. Russell, M.I.C.E., M.I.Mech.E.

SYNOPSIS

The paper describes the steps taken to alter an existing cross-country mill so as to enable it to take as feed stock the product of a cogging mill. The bloom section was of such an area that the inclusion of a substantial tonnage in the cogging mill programme would not adversely affect the productivity of that mill. The mill has been designed to allow for the possible use of continuously cast material. By reducing to a minimum the number of sizes of bloom required for the mill, stocking problems have been facilitated. The roughing stands are designed to feed what is in effect two finishing trains so as to minimize loss of production due to roll changing. The mill is equipped to roller-straighten sections directly off the cooling bed. 1915

INTRODUCTION

THE ORIGINAL light mills at Round Oak were of the simple Belgian merchant type with 10 and 12in roll centres to handle a proportion of the local jobbing trade. The post-war reconstruction of the Round Oak plant included the replacement of these jobbing merchant mills by a modern high production unit. In due course an American design of 16/10in cross-country type was decided upon. The company hoped not only to extend the size range of its production but also to handle a greatly increased proportion of the local trade in light sections and small rounds.

The original cross-country mill

The 10 and 12in merchant mills were dismantled and the new mill, installed on the same site, was commissioned in 1953. A general layout of the mill is given in Fig.1. It comprised an 18in three-high roughing stand, and a seven-stand 16in cross-country train, served entirely by skew roller tables. For the smallest products a two-stand 10in finishing mill was added to the layout. The product was received on a 210 ft double-sided mechanical cooling bed of the rack type, which was associated with two cold bar shears and back shear tables with loading pockets.

The plant was intended to be fed with blooms and billets of varying cross-section from 3in × 3in to 6in × 6in up to 15 ft in length so as not to burden unduly the single roughing stand, heated in an end-charged and discharged producer-gas fired continuous furnace with an effective hearth length of 50 ft and a design output of 20 tons/h. The furnace was equipped with an air recuperator of the metallic tube type. The various roll stands were driven by four motors: a 750 hp induction motor for the rougher, three 2:1 speed range dc machines of 2500, 1500, and 2000 hp respectively for the three cross-country groups, and finally a 650 hp motor of a similar speed range for the 10in finishing stands.

The products it was intended to roll are given in Table I.

Manuscript received 25 January 1960.

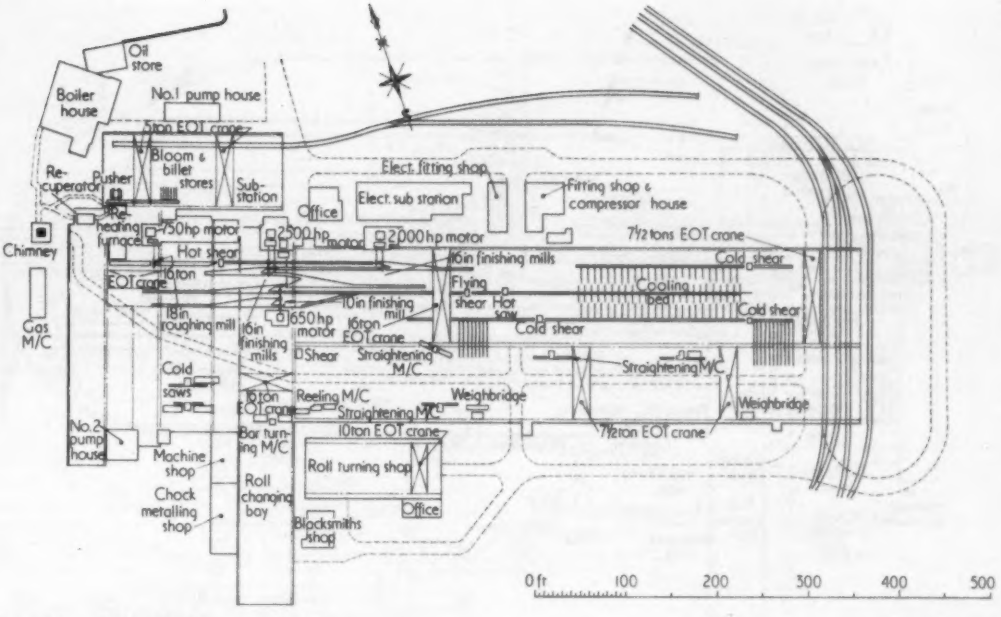
The authors were with Round Oak Steel Works Ltd, Brierley Hill, Staffs., when this paper was written.

Reasons for closure of original mill

The mill was operated as originally designed until 1957, when it was closed down, mainly because the inherently slow roll-changing times with a cross-country mill, the difficulty of securing suitable bulk orders, and lack of furnace capacity, made the plant uneconomic except on a limited range of products.

A changing production programme emphasized the difficulty of integrating this mill into the general rolling pattern of the works. Local conditions necessitated producing the range of feed stock sizes on the works 37in cogging mill, which also serves two other finishing mills. The smaller sizes required reduced the rolling capacity of the bloomer, making it difficult for it to absorb the increasing ingot capacity of the works, which has doubled over the last four years. A practice developed of supplying the cross-country mill with larger section feed stock, which militated against its performance, as the roughing stand became a serious bottleneck. The loss of heat during the extended roughing operations accentuated the difficulty, inherent in such a cross-country layout, of finishing products at a reasonable temperature. The finishing end of the mill contributed to the high conversion cost as all after-straightening of sections had to be done after cutting-up.

As the plant represented a substantial investment and there was a market for its products in the adjacent areas of the Midlands, and the South, it could not be



1 *General layout of mill before reconstitution*

scrapped. A solution, therefore, was sought to overcome these shortcomings and preserve what good features it possessed.

The desiderata of the mill

After considerable discussion it was agreed that any reconstruction must satisfy the following:

1. The feedstock must be a product of the cogging mill and of such a cross-sectional area that the inclusion of a substantial tonnage would not affect adversely the productivity of the cogging mill.
2. To facilitate stocking problems the range of bloom sizes must be kept to a minimum.
3. The non-productive time due to roll changing, etc., must be curtailed to ensure greater availability.
4. The heating capacity must be substantially greater.
5. All sections and flats must be finished in the line of production.
6. Small bars below around 1in² cross-sectional area, also other products, should be eliminated as far as commercially possible from the rolling programme. Alternatively, provision must be made to feed the mill, if necessary from purchased billets.
7. In view of the capital already invested in the plant, reconstruction costs must be kept to a minimum.
8. Utilization of the existing site should be improved.

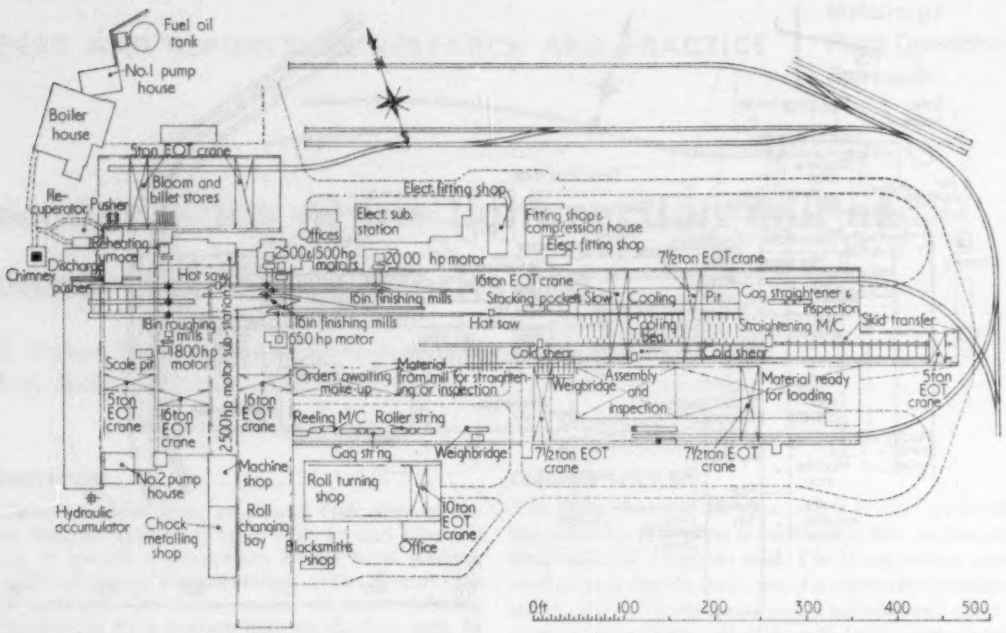
TABLE I Rolling programme

Product	Original size, in	Revised size, in
Rounds	½ to 4	1½ to 4½
Angles	1½ to 3½	2½ to 4×3
Channels	1½×½ to 5×3	3×1½ to 5×3
Joists	3×½ to 5×3	3×1½ to 5×3
Flats	1 to 6	3 to 6

The reconstructed mill

The revised rolling programme is set alongside the initial programme in Table I. Owing to the initial siting of the plant, close to the retaining wall of an old canal, the space at the furnace and roughing end was much restricted. Lack of space ruled out several obvious ways of effecting improvement in this region and precluded a solution of the initial section problem by the provision of a secondary mill behind the blooming mill to 'tailor' the product of the latter to suit the requirements of the cross-country mill.

While these preliminary investigations were in progress a demand arose for a substantial output of alloy steel rounds 3–4½in dia. which were larger than the 16in cross-country stands could handle and too small for efficient production on the works' heavy finishing mill. At about the same time some quite excellent second-hand mill equipment, both mechanical and electrical, became available at a figure which would help materially in keeping down the cost of reconstruction. These circumstances determined the character of the changes required at the rolling end of the plant, and by then the improvements needed at the finishing end were settled. It was decided that three bloom sizes must suffice, namely 7in×6in for the majority of products, 5in×5in for the smaller rounds, and 8in×7in as stock for the large rounds. These would be supplied in 13–16 ft lengths to suit the available ingots. The average bloom weight runs about 1 ton. These bloom sections would afford adequate relief to the bloomer and enable it to reach its production target. The reduction of finishing costs was to be secured by the employment of a single-sided hot bank, by straightening sections and flats before cold-shearing, and by improved disposal and stocking facilities.



2 *General layout of mill after reconstitution*

General layout

The general layout finally adopted is shown in Fig.2, reproduced to the same scale as Fig.1 for comparison. The bloom yard remains unchanged but the furnace charging arrangements now include a bloom-receiving table with a traversing and separating device to improve bloom delivery to the charging roller table, which has been equipped with a weighing device, to aid production control.

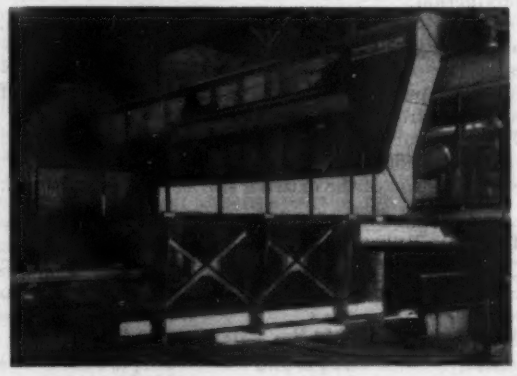
Furnace details

Site conditions coupled with the desire to utilize existing foundations as far as possible, caused the new furnace to occupy the same positions as its forerunner. The higher heating capacity was secured by changing to side discharging, which also allowed the effective hearth length to be increased some 5 ft. Oil fuel was substituted for producer gas to obtain a higher rate of heat release. The resulting triple-zone fired furnace has shown itself capable of heating at upwards of 40 tons/h at a fuel rate of about 10·5 gal/ton. It is equipped with a large metallic recuperator of the needle type, and a complete range of instruments. Up to the present, uniformity of heating leaves something to be desired. This is bound up with infiltration at the discharge door and an unsymmetrical utilization of the outlet ports. Steps are being taken to overcome these faults.

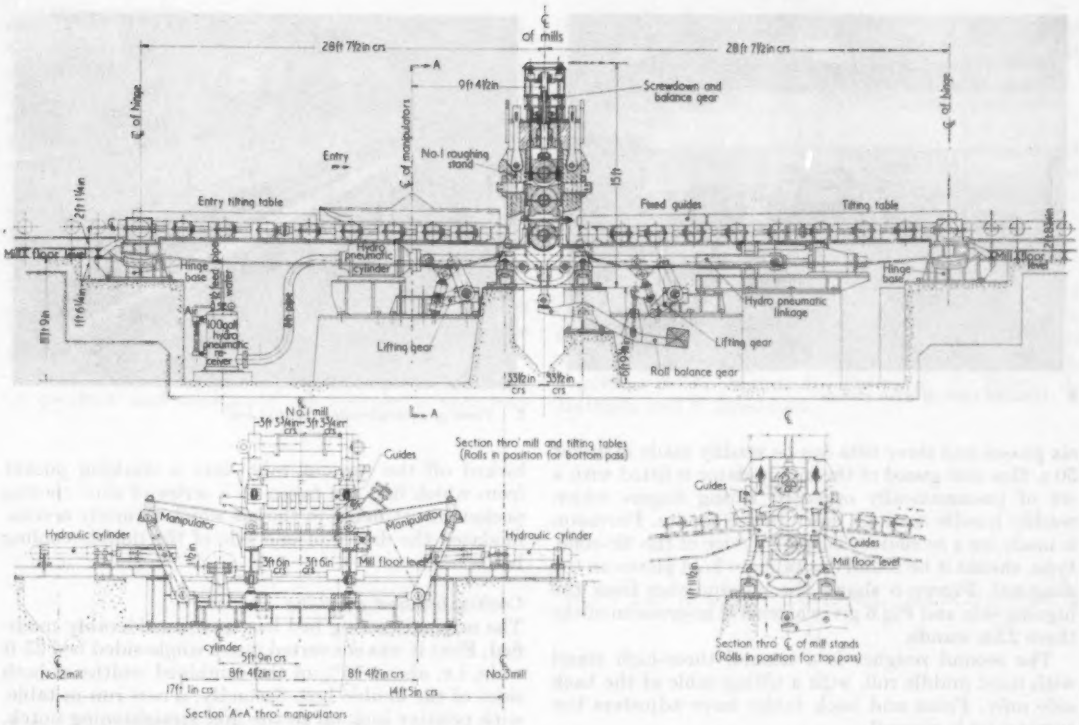
Roughing stands

The change in character of the roughing facilities is the most drastic alteration in the layout. The 18in rougher, which was only capable of making three passes without delaying the cross-country stands, has been replaced by a two-stand 22in three-high train. Nine passes can now be given a bloom in the time taken by the old rougher to make three passes. An additional 22in three-high stand is also installed on the same axis: this is driven separately and is primarily for finishing large rounds. It is so located as to be in line with the delivery table from the cross-country finishing stand. Heavy bars may be sent to the cooling bed, or diverted to a piling pocket behind the hot saw, for orders demanding slow cooling. The third 22in stand thus affords a means of maintaining productive operations during a change of the cross-country mill group, should the rolling programme permit. Provision has also been made for a fourth stand should trading conditions make it attractive at any time to produce heavier sections than the 16in mill can roll.

The axis of the 22in train was moved down the mill some 23 ft to enable a start to be made on the foundations before ceasing operations on the old rougher, and also to make room for the bloom-receiving table from the furnace. The 16 ton EOT crane, which formerly



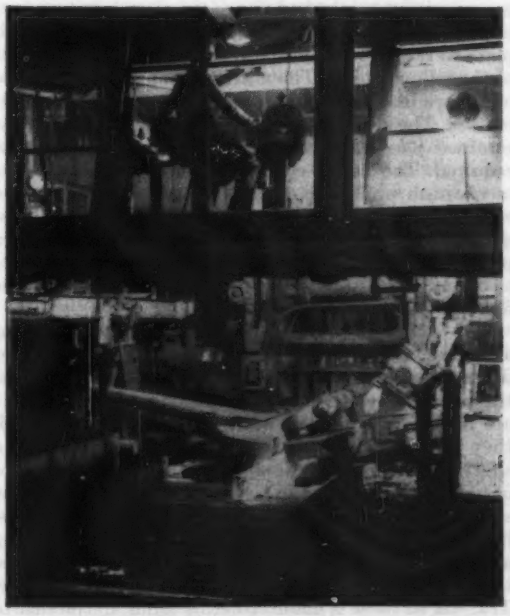
3 *Finger type overhead bloom transfer*



4 *Details of first roughing stand*

served the old rougher, has been transferred to the adjoining bay to cover the 22in train and its roll storage area.

The first roughing stand is of the adjustable roll type, the first time this useful variant of the three-high mill has been employed in Britain. It is sited between the second rougher for the 16in mill and the No.3 stand, so that bars can be skidded to either stand from its front table. This location entailed developing a somewhat novel overhead bloom transfer from the furnace discharge table to avoid interference (Fig.3). This transfer is of the finger type and is rope hauled by a fixed winch unit. It has proved a speedy and convenient device for feeding the centrally located first roughing stand. Blooms are stripped off the fingers by an inclined plate at the side of the ingoing table.



5 *First roughing stand from in-going side*

With the two drives, the first rougher can be driven from either side. Normally it is connected to the second rougher but should rolls have to be changed on this stand, as is necessary for certain shaped products, it is connected to No.3 stand so that rolling may continue with the least interruption.

Figure 4 shows the general features of the first roughing stand with its tilting tables on either side. These are hydraulically operated and hydro-pneumatically balanced; their lifting mechanism also actuates the middle roll lifting gear. The housings are of the open-topped type. The screw-down gear embodies a mechanical top roll balance and is self-contained on a combined housing caps and distance piece. The stand is served by a light sideguard manipulator carried on the ingoing table with its actuating elements mounted on the foundations. The rear table is provided with fixed guide plates set in line with the roll collars, as the piece is only traversed on the front side. This manipulator, in conjunction with the adjustable roll feature, enables a 'general purpose' roll design to be employed so that changing only occurs for wear. The first roughing mill has proved speedy and flexible in operation,

6 *General view of 22in stands*

7 *View of reconstructed cooling bed*

six passes and three tilts can be readily made in under 50 s. One side guard of the manipulator is fitted with a set of pneumatically operated tilting fingers which readily handle sections down to 4in square. Provision is made for a secondary turning device of the 'fir-cone' type, should it be found desirable to hold pieces on the diagonal. Figure 5 shows the manipulator from the ingoing side and Fig.6 gives a general impression of the three 22in stands.

The second rougher is a normal three-high stand with fixed middle roll, with a tilting table at the back side only. Front and back tables have adjusters but turning-up is manual.

Both roughers are driven by a 2300 hp dc rectifier-fed motor with a 2:1 speed range through a single reduction gear set with overhung flywheels on the pinion shaft. The roll speeds are 70–140 rev/min. The third stand has a similar motor of 1800 hp, also with a gear set giving roll speeds of 100–200 rev/min.

The product may be divided at an electrically driven down-cutting shear located in the connecting table between the second rougher and the first 16in stand.

Cross-country train

The cross-country stands have not been much improved except for the provision of face-mounted cramp bars, better water connexions for quick changing, and half universal leading spindles to reduce transmission backlash. Also the finishing stand has been individually driven by a 650 hp dc motor with a 2:1 speed range through a gear reducer to give roll speeds of 121–243 rev/min. Future improvements envisaged in this section of the plant include: better roll neck bearings and axial adjustment of rolls; repeaters for bars up to 1½in dia. and narrow flats; better facilities for rolling flats, generally comprising two underdriven, removable edging stands and simultaneous screw gears at the penultimate and finishing stands. Automatic turning devices are also desirable in front of the first, second, and fourth stands. These refinements were not undertaken during the major reconstruction owing to the restriction on capital outlay.

Originally the product was cut to hot bed length by a 42in pendulum saw, or, in the case of bars ¾in dia. and below, by a pneumatically operated flying shear. The saw has been retained and its duties are widened to include cutting up large rounds and joists which do not lend themselves to cold shearing. The former are kicked off the run-out table into a stacking pocket from which lifts are taken to a series of slow cooling pockets constructed in the pit which formerly accommodated the drives of one side of the double cooling bed.

Cooling bed and finishing

The original cooling bed has been considerably modified. First it was converted into a single-sided bed 35 ft wide, i.e. about 75% of the combined widths of both sides of the double bed. Secondly, a new run-in table, with positive kick-off to the first straightening notch, replaced the old swivelling conical rollers. The table consists of individually driven rollers, slightly skewed, to ensure that bars hug the face of the push-off plate when running down the table. First, on contacting a flag switch, the rollers dip enough for the bar to be braked rapidly by the floor plates. On coming to rest it is pushed off over its whole length to slide into a deep straightening notch whence the moving rakes traverse it across the bed. Since the piece is cut up into hot bed lengths by saw, there is time for the push plate to return to its initial position before the advent of the following bar. The moving elements of each side of the original design of bed were balanced, an unusual feature. The additional width given the side which was retained has upset this so that more power is now required. The bed is cleared by the usual shuffle bar mechanism which can assemble batches of bars on the cold run-out table. A general view of the reconstructed cooling bed appears in Fig.7, which also takes in a portion of the run-in table of the cold shear for sections. In the distance the roller straightener may be discerned.

The cold run-out table delivers in two directions according to product. Sections and flats run further down the mill to enter a 16in eight-roll straightener of the overhung roll type, after passing which the bars are received by a roller table 180 ft long from which they are cleared and moved onto a return table by a short-stroke positive dipping finger transfer. Batches of bars assembled on the latter table are run up to the section shear. Here they are cut to ordered lengths, before discharge sideways into the adjacent stocking and loading bay by two sets of uphill chain transfers, to assembling tables carried on a weighing machine. Transfer to these is made either by hand, in the case of light pieces, or with an overhead swinging stacking

and 'nesting' device provided with magnet grips. Completed stacks are removed by the loading-bay cranes either to stock or to despatch by rail or road. Section finishing is thus quite well mechanized. The section finishing arrangements have worked well, and any difficulties with handling the long bars at the straightener have been overcome.

Round and square bars leave the cold run-out table in the opposite direction to sections. Here a second heavy cold shear of the up-cutting type cuts them into ordered lengths or multiples, if the former are too short for conveyance by the roller tables. Behind the shear is a transfer with stacking pocket within reach of the loading bay cranes. Alternatively, bars can be pushed off into stacking pockets in the rolling bay.

After-finishing operations on bars depend upon class of product and customers' requirements, and may include re-shearing, reeling, machining, and surface inspection. These subsidiary operations are carried out in both bays.

CONCLUSION

In its present state of development the mill is best adapted to section production; before it is as efficient on bars and flats, the refinements alluded to in connexion with the cross-country stands are desirable.

ACKNOWLEDGMENTS

The authors wish to thank the Directors of Round Oak Steel Works Ltd for permission to publish this information, and colleagues who have been associated with this project, particularly Messrs J. Peddie, H. Bennett, B. L. Nixon, R. Paterson, A. Davis, A. Harthill, and F. Braddock.

AFFILIATED LOCAL SOCIETIES

Vacuum steelmaking

A. M. Samarin

SYNOPSIS

The use of vacuum in steelmaking provides a flexible control of the quality of the final product. The conditions for melting and pouring steel under vacuum are considered together with the kinetics of the process. Steel melted under a vacuum, using carbon as the deoxidizing agent, has a low concentration of dissolved oxygen and is free from deoxidation products. When melting stainless steel scrap in a vacuum induction furnace, decarbonization may be achieved with low chromium loss.

Methods available commercially for the vacuum treatment of steel are considered, and future developments and possibilities of the processes are discussed. 1945

THE APPLICATION of vacuum has opened up new opportunities of improving the processes of steelmaking and the quality of steels and alloys. Until recently metallurgists could use only change of temperature to improve the efficiency of steelmaking furnaces; now they have an additional means at their command: change of pressure; and this in many cases is more effective than change of temperature. It is not by chance that smelting of steels and alloys in different vacuum furnaces, vacuum treatment of liquid steel, and pouring of steel and alloys in vacuum have developed rapidly during the past decade. Not long ago the application of vacuum technology was restricted to the field of high-reactive metals production. Now annually many hundreds of thousands of tons of high-temperature alloys, and tool and constructional steel are treated or poured in vacuum conditions. In the near future millions of tons of steel and alloys of different composition will be manufactured with the application of vacuum. This rapid advancement of vacuum metallurgy is predetermined by the fact that in many cases application of vacuum has radically improved the properties of steels and alloys, thereby providing the successful solution to many complex problems of modern technology.

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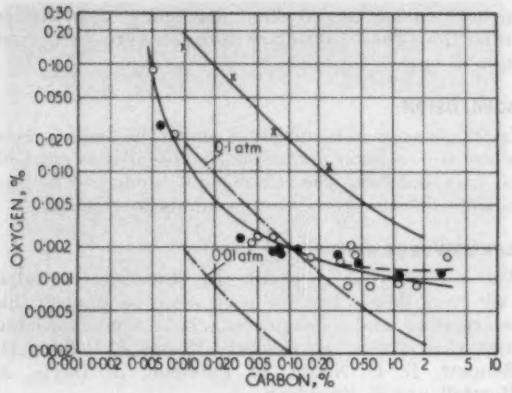
The author, who is a Corresponding Member of the Soviet Academy of Sciences, delivered this paper on 14 November 1960 as a lecture at a Joint Meeting of The Iron and Steel Institute with the Sheffield Metallurgical Association and the Sheffield Society of Engineers and Metallurgists.

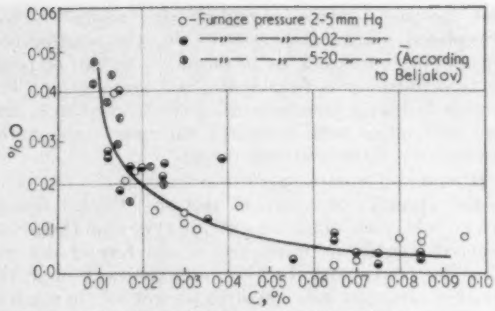
The Chairman of the Joint Meeting was Professor A. G. Quarrell (*Vice-President*). A vote of thanks was proposed by Mr W. C. Heselwood (President, the Sheffield Metallurgical Association) and seconded by Professor R. J. Sarjant (President, the Sheffield Society of Engineers and Metallurgists).

DEOXIDATION OF LIQUID METAL WITH CARBON IN VACUUM

When steels and alloys are produced in furnaces with an oxidizing atmosphere, the oxidation of liquid



1 *Dependence between %O and %C at 1590°C at different pressures*



2 *Carbon dioxidizing ability in a liquid* Cr–Ni *steel*

metal is usually unavoidable. By introducing deoxidizers, carbon, silicon, aluminium, and others, into the liquid metal, the concentration of oxygen dissolved in metal may be reduced to very low values. If the oxides, the products of deoxidation reaction, are insoluble in liquid metal, and are fully removed from the metal, it is possible to obtain steel and alloys with very low concentrations of dissolved oxygen and a low content of oxide non-metallic inclusions.

However, it is impossible to obtain steel and alloys absolutely devoid of non-metallic inclusions. If in a liquid metal, owing to the presence of some deoxidizing agent, the oxygen concentration was brought down and the oxides of the deoxidizing agent were fully removed from the metal, it would still be obvious that when the temperature diminished owing to diminution of oxygen solubility and to a fuller exothermic reaction of deoxidation, a certain amount of the oxides of the deoxidizing agent would reappear. The conditions for the removal of oxides would have become unfavourable, and oxides would remain in the metal in the form of non-metallic inclusions.

In contrast with other elements, carbon interacting with the oxygen dissolved in metal, forms a gaseous oxide which can be considered as insoluble in metals. The equilibrium constant of the reaction

$$[C]+x[O]=CO_{x(g)} \quad \ldots\ldots(1)$$

when the C content in iron is below 1%, as has been shown earlier,[1] may be represented by the equation

$$K_C=\frac{P_{CO_x}}{[\%C]\,[\%O]^x} \quad \ldots\ldots(1a)$$

It is a function of temperature only and therefore the value of $[\%C].[\%O]^x$, at the given temperature is determined by the value of P_{CO_x}. It follows, that the diminishing of the P_{CO_x} value should be accompanied by a drop in the product of $[\%C].[\%O]^x$ or in other words by an increase in the deoxidizing power of carbon. This is one of the important advantages determined by the employment of vacuum in steel smelting. The lowering of the pressure, when carbon is used as the deoxidizing agent, ensures the production of steel with a low concentration of dissolved oxygen, and free from deoxidation products. When transformer steel was smelted in high-frequency induction furnaces with a capacity of 20 and 150 kg at a pressure of about 1 mm Hg it was established that the value of $[\%C] \times [\%O]^x$ varies from 0·00002 to 0·00007. Hence, the drop of pressure by 1 mm Hg has resulted in almost a 100-fold increase in the deoxidizing power of carbon in some of the heats.[2] These results indicated one of the limitations that should be borne in mind when determining the limit of carbon deoxidizing power in vacuum. Indeed, the furnace pressure, as has been noted, was reduced 760-fold, while the increase in the carbon deoxidizing power was only 100-fold at best.

The carbon deoxidizing property in vacuum was determined by holding liquid iron with different C content at a given temperature (1590°C) until an equilibrium set in between iron, dissolved carbon, and oxygen.[3] In Fig.1 the upper continuous curve shows the equilibrium with the gaseous phase consisting of CO and CO_2. The crosses on the same curve stand for the equilibrium between carbon and oxygen in the liquid phase in the argon atmosphere at a pressure of 1 atm. One series of heats was carried out at a pressure of $5–7 \cdot 10^{-6}$ mm Hg, another at a pressure of $1–5 \cdot 10^{-2}$ mm Hg. The metal temperature was measured by the Pt/Pt–Rh thermocouple. Crucibles of aluminium oxide were employed and some three or four heats were made in them before the experiments so as to remove the interaction of the crucibles with iron containing 0·8–1·0%C. The dependence between the carbon and oxygen content in iron at 1590° is shown in Fig.1: in the heats at a pressure of $1–5 \cdot 10^{-2}$ mm Hg by dots, and at a pressure of $5–7 \cdot 10^{-6}$ mm Hg by circles. As shown here, the deoxidizing power of carbon proved to be much below that estimated from the value of the reaction equilibrium constant (equation 1*a*). The experimentally obtained points at pressures 10^{-2} and 10^{-5} mm Hg are located almost at the same curve. In other words, the pressure change in the furnace space by more than 1000-fold did not affect the deoxidizing power of carbon.

During the decarbonization of liquid nickel–chromium stainless steel in an induction-vacuum furnace, as shown in Fig.2, the lack of dependence of the deoxidizing ability of carbon upon the furnace space pressure was discovered.[4] Such results are natural for the reaction in a volume of liquid metal with the formation of a new gaseous phase. The difference between the estimated and experimentally determined deoxidizing power of carbon in vacuum has been caused by the erroneous interpretation of the P_{CO_x} value in the constant equilibrium equation.

The value of P_{CO_x} above the metal determined the relation of carbon and oxygen concentrations in the

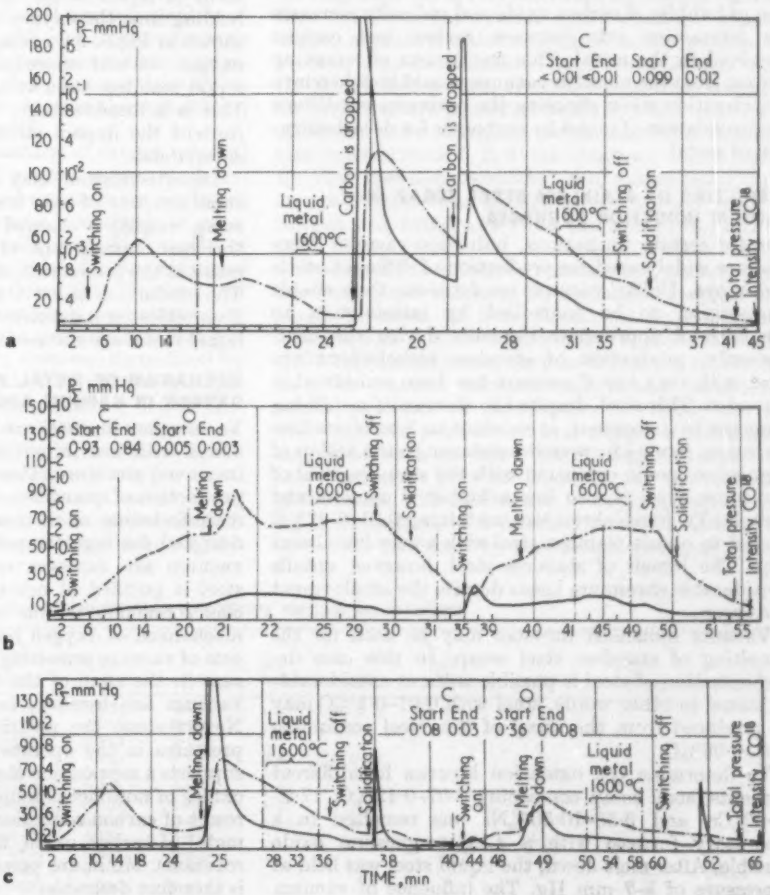
metal surface layer only. If the carbon and oxygen interaction takes place in the liquid metal volume then P_{CO_z} is determined by the barometric pressure over the metal: the pressure created by the column of metal at a given depth and the pressure predetermined by the surface tension forces on the bubble surface with radius, τ, i.e.:

$$P_{CO_z} = P_{bar} + \gamma h + 2\sigma/\tau \quad \ldots\ldots(2)$$

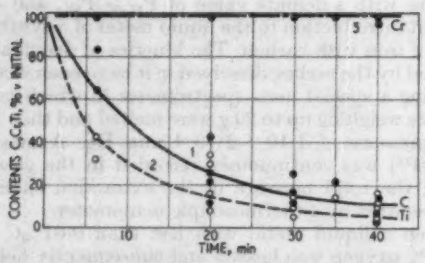
where P_{bar} is barometric pressure over the metal, γ liquid metal density, h metal bath depth at the level of the bubble formation, and σ is liquid metal surface tension. The influence of the vacuum upon the deoxidizing power of carbon is determined by the relation between the values of P_{bar} and $\gamma h + 2\sigma/\tau$. If $\gamma h + 2\sigma/\tau \gg P_{bar}$, then further pressure drop over the metal does not alter the value P_{CO_z}, i.e. cannot cause a further increase in the deoxidizing power of carbon.

To reveal the influence of certain factors upon carbon deoxidizing power in vacuum, the kinetics of iron decarbonization were studied by fixing carbon oxide in the gaseous phase of the furnace space, the product of an interaction between carbon and oxygen dissolved in liquid iron.[5] The master alloys of iron, carbon, and oxygen were prepared from electrolytic iron purified in hydrogen and saturated by oxygen at 1580–1630°C by holding under steam–hydrogen mixture with a definite value of $P_{H_2O}:P_{H_2}$, and subsequent introduction to the liquid metal of a synthetic alloy of iron with carbon. The kinetics of deoxidation of metal by the carbon dissolved in it have been studied by using a special mass-spectrometer in which metal samples weighing up to 20 g were melted and then held at a pressure of $1 \cdot 10^{-3}$–$1 \cdot 10^{-4}$ mm Hg. A mass of 30 (CO^{18}) was continuously recorded in the gaseous phase; the total pressure in the extraction chamber was recorded by a thermocouple manometer.

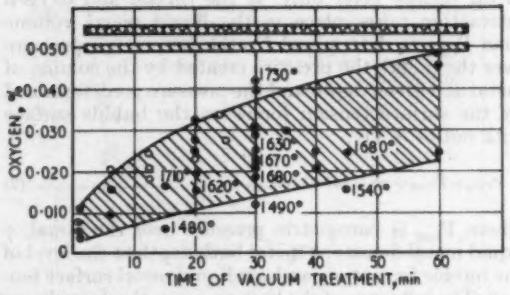
When a liquid metal with less than 0·01%C and 0·099% oxygen was heated and subsequently held at 1600°C, the total pressure increased noticeably while the amount of CO^{18} which was evolved during the process was insignificant. Apparently the conditions for carbon and oxygen interaction in the metal volume with the formation of the bubbles were unfavourable and the reaction had taken place only on the surface of the metal, i.e. the CO^{18} evolving rate was small. Only by introducing an alloy of iron with carbon into the liquid metal can a radical increase in the CO^{18} evolving rate, due to the development of carbon–oxygen reaction in the metal volume, be observed. The rimming of metal following carbon introduction, however, soon finishes. Despite carbon additions to the metal, the C content remained below 0·01% while oxygen content was reduced from 0·099 to 0·012%. The graphic variation of total pressure and CO as



3 *Change in general pressure and separation of* CO^{18} *from liquid iron in a vacuum*



4 *Influence of vacuum holding time upon the reduction of Cr, C, and Ti content in liquid metal*



5 *Influence of vacuum holding time upon oxygen content in metal*

determined by mass spectrometry in the gaseous phase is shown in Fig.3. At vacuum holding of iron with 0·92%C and 0·005% oxygen no noticeable evolution of CO^{18} from the metal was observed, i.e. the decarbonization reaction probably did not take place in the metal volume. CO^{18} was evolved in noticeable amounts in vacuum from iron containing 0·08%C and 0·03% oxygen only at the moments of fusion and solidification.

These data indicate that the development of carbon–oxygen interaction is predetermined not only by the concentration of these elements but by the physical state of the liquid metal. The presence of a solid phase in the liquid metal facilitates the formation of bubbles of carbon oxide and radically increases the interaction rate between carbon and oxygen dissolved in the metal. This mechanism of removing oxygen from the metal in vacuum should be taken into consideration when choosing the optimum conditions for deoxidation of metal by carbon or for decarbonization of metal.

REMELTING OF STAINLESS STEEL SCRAP IN VACUUM INDUCTION FURNACES

Despite certain limitations, induction-vacuum furnaces are widely used for production of different steels and alloys. Unlike vacuum arc furnaces, they enable composition to be controlled by introduction to the bath of appropriate elements during the heat. Recently, production of stainless nickel–chromium steel with very low C content has been considerably extended. This steel, despite the absence of stabilizing elements in its content, is resistant to intercrystalline corrosion, having increased resistance to the action of aggressive agents compared with the stainless steel of the same type; it also has a higher C content and includes Ti. Ferro-chromium containing 0·01–0·02%C is used to obtain stainless steel with a very low C content. The remelt of stainless steel, however, entails considerable chromium losses despite the employment of oxygen.

Vacuum induction furnaces may be used for the remelting of stainless steel scrap. In this case decarbonization of steel is possible without considerable Cr losses; in other words, steel with 0·01–0·2%C may be produced from the scrap of this steel containing 0·07–0·09%C.

To determine the oxidation kinetics for different elements, steel scrap containing 0·07–0·12%C, 17·2–21·0%Cr, and 9·50–10·50%Ni was remelted in a laboratory furnace with a 4-kg magnesium oxide crucible. After melt-down, the liquid steel was held at a pressure of 2–7 mm Hg. The influence of vacuum holding time upon the degree of Cr, C, and Ti oxidation is shown in Fig.4. The production of stainless steel by remelting its scrap with a high C content is accompanied in these conditions by an insignificant oxidation of Cr: the maximum chromium loss was 3·7% of the initial content of this element in the scrap. As a result of a 20-min holding in the vacuum, C content in the steel of several heats was reduced to 0·01–0·02%. Naturally, holding in vacuum entails almost complete oxidation of titanium.[6] Remelting of high-Cr steel scrap in vacuum furnaces with a magnesium-oxide crucible is accompanied by the enrichment of liquid metal with oxygen; with increase in holding time the oxygen content in the steel grows as shown in Fig.5. As a result of 1-h holding in vacuum, oxygen content approximated its solubility limit in liquid stainless steel at steelmaking temperatures.[7, 8] This is a disadvantage, for with increase in oxygen content the impact strength of Cr–Ni stainless steel deteriorates.

Decarbonization may be accelerated, provided a small amount of iron ore (not more than 1% of the scrap weight) is charged together with the scrap. In this case curtailment of vacuum holding time will result in the production of steel with a lower C content. The production of low-C stainless steel will be possible if crucibles for induction-vacuum furnaces inert to the liquid metal are successfully evolved.

MECHANISM OF METAL PURIFICATION FROM OXYGEN IN VACUUM ARC FURNACES

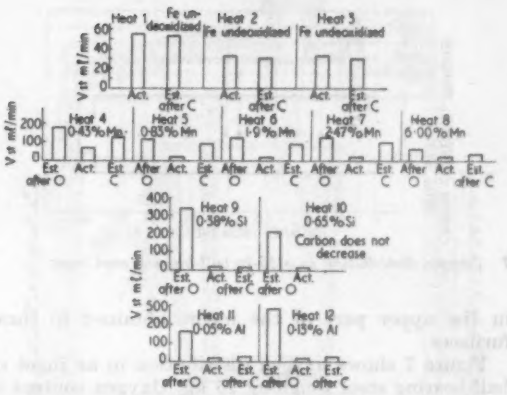
Vacuum arc furnaces are used for obtaining steels and alloys with low impurity content, and for ingots of improved structure. These furnaces are employed for production of quantities of steel and alloys used in the manufacturing of instrument bearings and bearings designed for high-temperature service. Remelting in vacuum arc furnaces ensures that Cr ball-bearing steel is purified of non-metallic oxide inclusions. In this connexion it was expedient to determine the mechanism of oxygen removal from steel in the process of vacuum remelting. Determination of true pressure in the zone of the highest temperatures in the vacuum arc furnaces is difficult if not impossible. Nevertheless, the possibility of achieving very low pressures in the operational space of these furnaces supports a supposition that the decrease of oxygen and oxides of non-metallic inclusions in bearing steels is a result of carbon reduction and the evolution from the metal of carbon oxide, the gaseous product of these reactions. Minimum pressure in vacuum arc furnaces is therefore desirable.

TABLE I Variation of oxygen content during vacuum arc remelting of ball-bearing steel

Steel	Heats	Oxygen content before remelting	Oxygen content after remelting	Pressure in furnace, mm Hg
Normal	1	0·0040	0·0017	$1 \cdot 10^{-1}$
	2	0·0040	0·0018	$8 \cdot 10^{-2}$
	3	0·0040	0·0015	$3 \cdot 10^{-2}$
	4	0·0040	0·0019	$1 \cdot 10^{-2}$
	5	0·0035	0·0021	$1 \cdot 10^{-2}$
	6	0·0040	0·0019	$3 \cdot 10^{-4}$
	7	0·0040	0·0020	760 argon atmosphere
	8	0·0045	0·0022	
	9	0·0029	0·0015	
Unkilled with Al	10	0·0056	0·0013	$1 \cdot 10^{-1}$
	11	0·0045	0·0023	$4 \cdot 10^{-2}$
	12	0·0025	0·0013	$1 \cdot 10^{-2}$
	13	0·0027	0·0013	$1 \cdot 10^{-2}$

Experimental study of smelting in vacuum arc furnaces has shown that the degree of metal purification from oxygen is not directly dependent upon the pressure in the space of these furnaces. Table I lists data on the change in oxygen content in the Cr ball-bearing steel remelted under different pressures in a vacuum arc furnace. In this table the term 'Normal' denotes steel which was deoxidized by aluminium; for comparison, data are presented on the removal of oxygen from a similar steel which has not been deoxidized by aluminium. From these data it is clear that the degree of purification of ball-bearing steel from oxygen was almost the same although furnace pressure varied by more than 100-fold. This is an indirect indication that the reduction of those non-metallic inclusions which are difficult for reduction through carbon has not been studied sufficiently.

To reveal the possible mechanism of oxygen removal from metal during remelting in arc-furnaces, to determine change in the content, we altered the evolution rate of carbon dioxide during remelting of non-deoxidized and deoxidized mild iron. The results of this experiment are listed in Table II. Regardless of the deoxidizing agents introduced into the iron, remelting in the vacuum arc furnace is accompanied by a noticeable decrease in oxygen content. Remelting of non-deoxidized iron, and iron that was deoxidized by manganese, results in metal decarbonization. The decrease in C content during the remelting of iron that was deoxidized by silicon or aluminium is insignificant. It follows from the data in Table II that the stoichiometric relation between the decrease of oxygen and C content in iron does not occur. This inconsistency has been illustrated in Fig.6 where the estimated separation rate for carbon monoxide is shown; it was assumed that



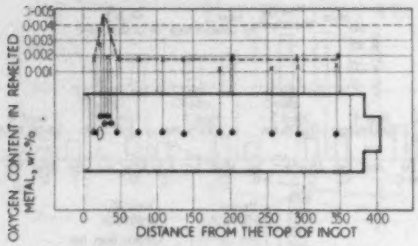
6 *Separation of carbon monoxide from metal in a vacuum arc furnace*

the entire carbon in non-deoxidized iron was oxidized by oxygen dissolved in metal, and CO, the product of this reaction, evolved from the iron. The values of the estimated evolution rate of CO from iron deoxidized by manganese, silicon, or aluminium are also given. Estimation of the evolution rate has been made, proceeding from the assumption that all oxygen removed from the metal had reacted with carbon and that the carbon monoxide which originated in the process had evolved from the deoxidized iron. The measured values for the evolution rates of carbon monoxide from iron for each heat are presented in Fig.6, which shows that estimated and determined carbon monoxide evolution rate values (heats 1, 2, 3) are identical. This supports the view that non-deoxidized iron, during remelting in an arc-furnace, was deoxidized by carbon, and the oxygen was withdrawn from the iron in the form of CO.

A substantial difference between the estimated and the determined values of CO evolution rates has been found in heats of iron deoxidized by manganese (heats 4, 5, 6, 7, 8), ferrosilicon (9, 10), and aluminium (11, 12). This difference may be explained by the fact that the reaction between carbon and particles of oxides, products of deoxidation reactions, had not developed and purification from oxygen in these heats may be taken as a result of the floating of non-metallic oxide inclusions from the metal during the remelting of the latter. This mechanism of oxygen removal during the remelting of deoxidized metal in vacuum arc furnaces is confirmed by the increased oxygen content

TABLE II Variation of certain elements contents in iron during vacuum arc remelting

Iron	Heats	Contents, % O before	O after	C before	C after	Mn before	Mn after	Si before	Si after	Al before	Al after
Undeoxidized	1	0·1380	0·1360	0·024	0·019	...	...	...	...	...	...
	2	0·1370	0·1260	0·040	0·035	...	...	...	...	...	...
	3	0·2000	0·1960	0·042	0·035	...	...	...	...	...	...
Deoxidized with Mn	4	0·0930	0·0630	0·025	0·013	0·43	0·33	...	...	...	...
	5	0·0280	0·0090	0·013	0·012	0·83	0·61	...	...	...	...
	6	0·0230	0·0050	0·025	0·015	1·90	1·23	...	...	...	...
	7	0·0195	0·0020	0·038	0·028	2·47	1·52	...	...	...	...
	8	0·0130	0·0029	0·033	0·029	6·00	4·17	...	...	...	...
Deoxidized with Si	9	0·0710	0·0110	0·055	0·054	...	...	0·38	0·29	...	...
	10	0·0575	0·0204	0·033	0·033	...	...	0·65	0·61	...	...
Deoxidized with Al	11	0·0960	0·0995	0·040	0·038	...	...	...	...	0·130	0·090
	12	0·0154	0·0090	0·042	0·041	...	...	...	...	0·196	0·191



7 *Oxygen distribution in a 25-kg ball-bearing steel ingot*

in the upper part of the ingots obtained in these furnaces.

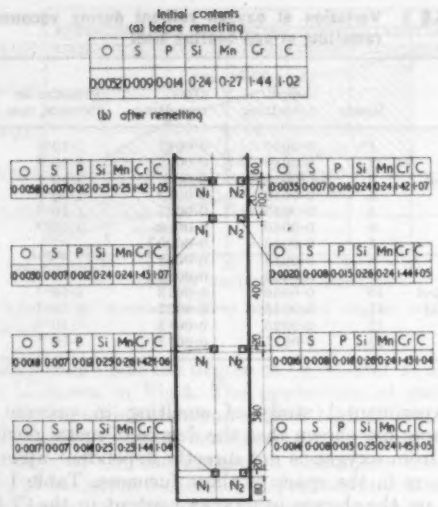
Figure 7 shows oxygen distribution in an ingot of ball-bearing steel weighing 25 kg. Oxygen content is even throughout the ingot; it increases only in the upper part, and just beneath the shrinkage cavity surpasses the oxygen content that was in the steel before remelting. The distribution of carbon, sulphur, and oxygen in the volume of a ball-bearing steel ingot weighing 500 kg obtained in another vacuum furnace is shown in Fig.8. In the upper part of this ingot too, there is an increase in oxygen content; before remelting, this steel contained 1·02%C, 0·009%S, and 0·003% oxygen. The mechanism of metal purification in the vacuum arc furnace remelting process should be taken into consideration when choosing the main parameters of this process, chiefly in the choice of the optimum pressure.

When discussing the mechanism of metal purification from oxygen in vacuum arc furnaces it should be borne in mind that such deoxidizing agents as manganese, silicon, and aluminium have high vapour pressures at steelmaking temperatures. The data presented in Table II indicate a considerable drop in the Mn, Si, and Al content during remelting in a vacuum arc furnace of iron deoxidized by these elements. The evaporation of these elements may result in the acceleration of the oxide particles floating in the metal, i.e. facilitate the purification of the metal from oxygen. Additional study is needed into the possibility of purifying metal by the evaporation of suboxides of such deoxidizing agents as silicon and aluminium.

LIQUID-STEEL VACUUM TREATMENT

It is hardly possible that millions of tons of steel will be produced annually in vacuum induction and vacuum arc furnaces very soon, but these amounts will be attained in the future in steel production, using installations for treatment and pouring of steel in vacuum. Iron and steel mills are already making extensive use of various methods of vacuum treatment or vacuum pouring of steel. What are the requirements of methods and installations designed for vacuum treatment or pouring of steel?

Both the treatment and pouring of steel in a vacuum should not disrupt the normal production cycle in modern steelmaking shops: these operations should be conducted with the least expenditure of additional time and without the use of complex additional equipment that has to be located in the shop, and installations for treatment or for pouring which are certainly necessary, should not complicate pouring operations and should be cheap. Also, the expenditure associated with the operation of the



8 *Oxygen distribution in a 500-kg ball-bearing steel ingot*

installations for the treatment or pouring of steel in a vacuum should be low. Apparently all installations for casting big ingots in a vacuum are very much alike and mostly meet these requirements. In a lesser degree this applies to the methods of liquid-steel treatment and to the installations designed for the implementation of these methods. Some of the methods and installations are excessively complicated, and the very process of treatment renders production more complicated.

The method of liquid-steel vacuum treatment was suggested for commercial use in the USSR in 1940, from experience gained in observation of the behaviour of deoxidized steel under decreased pressure in a mould. In 1939–40 study was made of the change in the gas content of metal during the production of Cr–Ni steel in 30-ton electric-arc furnaces with bottom pouring of the steel into ingots each weighing 1200 kg. The gases which escaped from the steel during the filling of the mould were collected in a gas-holder. When water was accidentally let out from the gas-holder at a high rate, the pressure became below atmospheric in the enclosed space above the liquid steel surface. As a result, the well deoxidized steel in the electric furnace began to boil owing to the escape of gases from the liquid metal. In these conditions CO and H were evolved from the steel.[9]

After the Second World War, an installation for vacuum steel treatment was built at the Electrometallurgy Laboratory of the Moscow Steel Institute. The results obtained here corroborated the efficiency of the suggested method. The sound ingots were obtained from steel that was deliberately saturated with hydrogen and then subjected to vacuum treatment. Ingots poured from the same steel but without vacuum treatment were swollen and had many blow-holes.

The liquid-steel treatment method was commercially employed at the Enakievo steel mill in 1952–53. Acid Bessemer steel was subjected to vacuum treatment in a 16-ton ladle, or four-ton ingots of acid Bessemer steel were vacuum poured.[10] The favourable results obtained at this mill encouraged the construction of installations for vacuum treatment of liquid steel at other steel works.

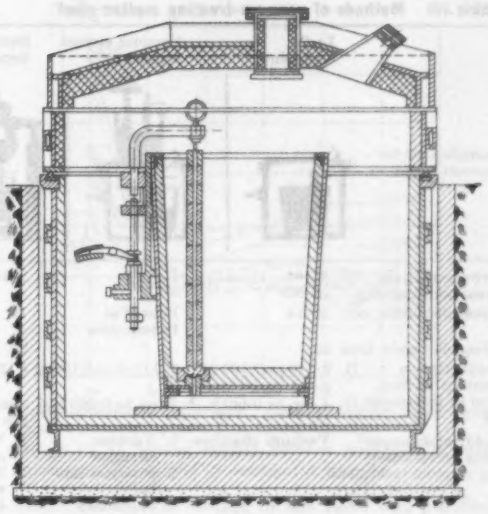
Figure 9 shows a chamber for treatment of 22 tons of liquid steel in a ladle. The welded steel casing of the chamber is placed in the pit, slightly rising over the pouring-side floor level. This positioning of the chamber limits the space occupied in the shop and does not disrupt the normal transport within the shop. A groove, with rubber packing to fill the space between the stable part of the chamber and the lid, runs around the upper edge of the lower and stable part of the chamber cylinder. The lid of the chamber has an observation port for watching the behaviour of the metal and the slag during treatment. A hermetically sealed container is set in the centre of the lid and through this container it is possible to introduce deoxidizers into the ladle at the end of vacuum treatment. The lid is coupled with a hinge joint to the stable part of the chamber; lifting or lowering of the lid is effected by a winch. These operations can therefore be carried out rapidly without holding up the ladle cranes of the pouring side.

The chamber is serviced by four rotary vacuum pumps, two of the RVN 30 and two of the RVN 60 type. Pressure of 2 mm Hg in the chamber is reached in 8 min after the beginning of gas exhaust from the chamber. A cyclone, a refrigerator, and filters are set between the vacuum chamber and the pumps.

The ladle with the liquid steel is installed within the vacuum chamber; this can be fulfilled in 1 or 2 min. When the ladle is installed, the lid of the chamber is lowered and the vacuum pumps are operated. Decrease of inter-chamber pressure is accompanied by evolution of gases from the steel, which is indicated by tongues of flame around the stopper and close to the walls of the ladle lining. The escaping gases break up the slag surface and the liquid steel is ejected through the slag layer. When minimum pressure is achieved within the chamber (2–20 mm Hg) the liquid steel and the slag rise in the ladle by 300–500 mm. After holding the steel for some time in the vacuum, gas escape becomes slower and the metal surface is again covered by slag. At this moment the vacuum pumps are switched off and the chamber is open to the atmosphere. When atmospheric pressure is established within the chamber, the lid is raised and the ladle is extracted from the chamber. Usually, vacuum-treated steel is poured in the open air.

A ladle with 25 tons of liquid steel in the chamber is held for about 12–15 min. Thus, the time from tapping the furnace to the beginning of pouring, requires, in vacuum treatment, an additional 15 min compared with the similar period in ordinary steel pouring. During this additional time steel temperature drops by 30–40°C.

At Soviet mills, carbon and alloy steels obtained from acid Bessemer converters, in OH and electric furnaces, are subjected to vacuum treatment. At the Dzerzhinskii mill, a ladle with liquid acid Bessemer steel is held in the chamber for 12–14 min. The steel is deoxidized after treatment and then poured in the air. When rail steelmaking in acid Bessemer converters is executed at this mill, air blowing is discontinued when a given high C content in the liquid metal is reached. After blowing, steel and slag are poured into a ladle which is then placed in a chamber. Steel samples are taken before the installation of the ladle in the chamber; the content of vacuum-treated metal is determined in a sample taken after the treatment and before the introduction of deoxidizing agents. As a result of this sort of vacuum treatment, oxygen content in acid Bessemer rail steel is decreased on the average by more than four-fold and reaches a very low value: 0·001%. This radical drop in oxygen content, without the application of deoxidizing agents to the steel, is an indication that under low pressure the deoxidation reaction of liquid steel by carbon develops. Hydrogen content in steel after the treatment is close to 2 $cm^3/100$ g, i.e. the content of this gas in acid Bessemer rail steel drops 2–2·5-fold. The N content in this steel drops only by 10–20%.



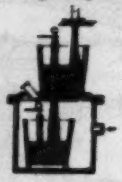
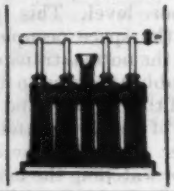
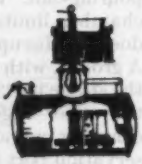
9 *Chamber for liquid-steel vacuum treatment*

After vacuum treatment the oxygen content drops five-fold in acid Bessemer rimming steel which has roughly 0·12%C; H content drops two-fold reaching 2–3 $cm^3/100$ g. During vacuum treatment of rimming steel a much greater amount of CO is evolved from it than rail steel and this facilitates fuller purification of rimming steel from nitrogen. Approximately 40%N is evolved from this steel during vacuum treatment.[11]

In vacuum treatment of alloy steel obtained and deoxidized in electric-arc furnaces, the reaction of deoxidation by carbon naturally does not develop to a noticeable extent. Under these conditions an insignificant purification of steel from oxygen is all that may be expected. Nevertheless, in deoxidized steels also, the oxygen content drops as a result of vacuum treatment. This drop should be understood as a result of deoxidation by carbon (carbon oxide has been always detected in escape gases) and as a result of floating of non-metallic oxide particles from the steel. Evolution of gases from deoxidized steel is accompanied by the mixing of liquid metal in the ladle; this accelerates the coalescence of oxide and silicate particles suspended in the steel. Hydrogen is removed during vacuum treatment of the steel simultaneously with the evolution of CO.

The vacuum chambers at the Dneprospetsstal' mill were first designed for treating in ladles alloy steels produced in electric-arc furnaces. Usually the holding time for a ladle with liquid steel in a chamber was 10–12 min. The residual pressure in the chamber, was

Table III Methods of vacuum-treating molten steel

	Ladle degassing	Vacuum stream degassing	Batch degassing	Circulation degassing	Vacuum casting	Multivacuum casting
Installations for vacuum treatment						
Pressure during treatment, mmHg	5–10* 15–20†	1–10	2–10	1–5	2	1–2
Treatment time, min	12–14	Poured at 10 tons/min	19	15	...	...
Weight of melt, tons	25	...	80	70	...	...
Reduction in content in steel, due to treatment, of	H 2·5 (2 cm³/100 g)* 2·5(2–3cm³/100g)† O 4 (up to 0·001%)* $5\times^{2}$	2–3 (1·8 cm³/100 g)	3 (2·2 cm³/100 g) almost 2 (up to 0·006%)§	Almost 2(4 cm³/100 g) ...	... ...	... ...
Additional apparatus necessitated by vacuum treatment	Vacuum chamber	1. Vacuum chamber 2. Intermediate ladle 3. Secondary steel teeming ladle	1. Vacuum chamber 2. Mechanism for moving the chamber into a vertical position 3. Jointed vacuum sealing 4. Apparatus for heating chamber 5. Secondary vacuum chamber	1. Vacuum chamber 2. Heating apparatus 3. Transporter gas 4. Secondary vacuum chamber 5. Jointed vacuum sealing	1. Vacuum sealing in each mould	1. Vacuum chamber 2. Vacuum duct 3. Intermediate ladle
Fireproofing	Highly fire-resistant material for the stopper rolls at slag level	Supplementary fireproofing on the linings of the intermediate ladle and secondary steel pouring ladle	Supplementary highly fireproof material because of the rapid wear of the suction pipe and chamber lining	Supplementary highly fireproof material because of the rapid wear of the standpipe and chamber lining	...	...

Steels: * Bessemer rail; † Bessemer rimming; ‡ Soft rimming; § OH, S35.

20–30 mm Hg. When transformer steel was vacuum treated, oxygen content decreased two-fold. As a result of vacuum treatment, transformer steel with a low H content was produced and therefore sound ingots were always obtained after pouring.

The structure of ingots cast from rimming steel changed radically owing to vacuum treatment. In internal structure and the presence of the shrinkage cavity, they did not differ from the ingots of deoxidized steel. A sufficiently homogeneous distribution of admixtures in the ingot volume should be ensured. The absence of blow-holes and less definite segregation in ingots cast from vacuum-treated rimming steel, ensured better quality of rolled sheet metal; the sheets rolled from these ingots proved to have a very homogeneous content. The sheets obtained from any ingot of vacuum-treated rimming steel are characterized by the absence of clearly expressed segregations.[12] Vacuum treatment noticeably improves the mechanical properties of acid Bessemer rimming steel. Transition temperature without the introduction of Al or V drops by 10–40°C. Vacuum-treated steel which has been additionally deoxidized by Al or V has a transition temperature within −30°C; this temperature reaches −50°C for the steel of certain heats. When transversal samples were tested for the thermal influence of welding upon impact strength, it was found that during the welding of vacuum-treated rimming steel the zone of thermal influence is almost non-existent and a certain decrease in impact strength was observed at the weld seam itself.

Vacuum treatment as such, by lowering the oxygen and H content in the steel, and because heat conditions can be controlled to ensure the production of steel with a lower C and S content, has beneficially influenced the transformer steel properties. When this steel is produced in electric-arc furnaces, steel with low content of such harmful admixtures as C and S may be produced by increasing the metal temperature. However, an increase in temperature entails swollen ingots which are unsuitable for thin cold-rolled sheet manufacture. As has been already noted, swollen transformer steel ingots were completely eliminated by vacuum treatment. Simultaneously, it has become possible to produce steel with lower C and S content. Before the employment of vacuum-treatment, C content in almost all transformer steel ingots was within the range 0·04–0·09% and S content not lower than 0·007%. C content in vacuum-treated steel is not higher than 0·03% and S content ranges from 0·003 to 0·005%. Vacuum treatment has made it possible to produce transformer steel of a greater purity from harmful admixtures of oxygen, hydrogen, carbon, and sulphur, with consequent improvement in the steel's properties. The decreased content of non-metallic inclusions in vacuum-treated transformer steel enables its plasticity to be improved. This in its turn opens up the possibility of increasing Si content in the steel.

These results achieved from liquid-steel vacuum treatment at Soviet mills are presented only as examples. They were obtained when liquid steel was treated in ladles.

At present, the following methods of liquid steel vacuum treatment are employed commercially:

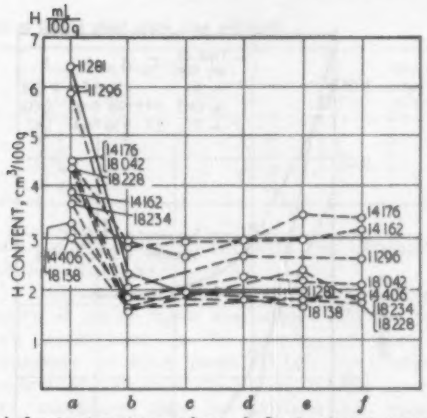
ladle degassing
stream degassing
batch degassing (vacuum-lifter process)
circulation degassing
casting of relatively small ingots in vacuum.

The diagrams of installations for the implementation of some of these methods are shown in Table III. Comparison of the installations cited shows that designed for steel treatment in a ladle as the simplest. What justification is there for the use of more complicated installations? It is possible that more complicated installations originated as a result of a desire to ensure better purification of liquid steel from gases in the process of vacuum treatment. There is still a widespread opinion that the vacuum treatment of liquid steel in a ladle ensures the purification from gases of the upper layers only of the metal, and that it is impossible therefore to hope for purification of the entire volume of steel in the ladle. This opinion is erroneous since it does not take into consideration the mechanism of gas evolution from liquid steel.

During vacuum treatment of liquid steel, H can be withdrawn comparatively easily. The purification of steel from oxygen and to a certain degree from N is associated with the development of the decarbonization reaction of, in other words, the deoxidizing of steel by carbon which is accompanied by the evolution of CO from the liquid steel. Evolution of CO is possible provided conditions exist for the formation of stable nuclei of CO and for their growth to a size when bubbles of this gas can escape from the liquid steel. The withdrawal of CO bubbles is not only a means for diminishing oxygen content but also of accelerating the purification of steel from hydrogen and nitrogen.

The formation of stable CO nuclei in the volume of liquid steel is difficult, if not impossible. Nuclei of this type originate on the interface of liquid steel and ladle lining, and mainly on the bottom of the ladle. This is confirmed by observation of vacuum treatment of steel in a ladle. At the very beginning of the treatment tongues of flame from the gas which escapes from the steel and is burned, appear at the walls of the ladle and around the stopper. Observation of gas evolution from a transparent liquid shows that this proceeds mainly because of the withdrawal of bubbles which have originated at the bottom of the vessel; the bubbles originating on the walls of the vessel do not effectively escape to the surface. Hydrostatic pressure influences the formation of CO bubbles[13] but when liquid steel is held in a ladle in a rarefied space, all conditions are ensured not only for their origination but also for a rapid evolution rate.

If the evolution of CO from steel begins during vacuum treatment the steel, throughout its volume, becomes practically homogeneous very quickly. The change in H content during acid Bessemer rail steel vacuum treatment in a ladle and during its pouring into moulds is shown in Fig.10. The first sample of steel is taken from a ladle before treatment and the second from a ladle after treatment; subsequently samples were taken before pouring the first, second, third, fourth, and fifth ingots. Owing to the complexity of the motion of liquid steel in the ladle during pouring it is impossible to state which portion of steel filled which mould, but it is certain that the H content of the entire volume of steel in the ladle was practically homogeneous. Hence, during steel vacuum treatment



a before treatment, upper layer; *b* after treatment, upper layer; *c–f* after pouring ingots 4, 3, 2, 1, respectively

10 *Change in* H *content during vacuum treatment of acid Bessemer rail steel and its subsequent pouring*

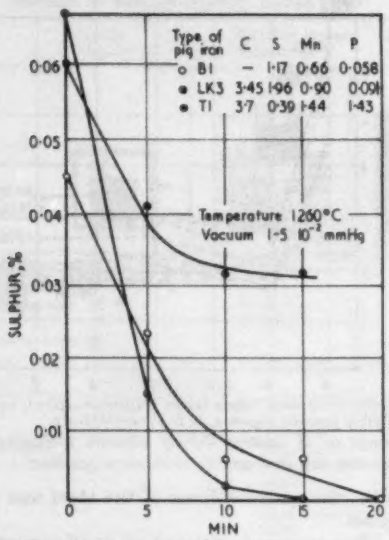
in a ladle, the entire volume of the steel was purified from gases.

The lifter-process treatment of small amounts does not differ in principle from the method of treatment in a ladle as regards conditions for the removal of gases from the steel. It is the same treatment in a ladle of a smaller size.

What are the advantages of these three methods? Do they provide for more beneficial conditions for the withdrawal of gases from steel? A stream of liquid steel encountering a vacuum does break up, but this is determined by the evolution of CO bubbles from the steel. Hence, in this case too, it is necessary to ensure conditions for the formation of stable nuclei of CO. The absence of an interface of liquid steel with some solid surface reduces the chances of origination of stable nuclei.

The employment of conveying gas during circulation facilitates the withdrawal of gas from steel, and the inert gas may also be employed for other methods of vacuum treatment.

The efficiency of one or other method of vacuum treatment should be judged by the results. A criterion for these results may be the change in gas content in the steel during the vacuum-treatment process. At present, some of the results obtained while using different methods have been published and therefore comparison of the methods is possible. Table III shows the data which make it possible to appreciate liquid-steel vacuum treatment methods and the installations necessary to put them into practice. A strict comparison of the methods should be carried out during the vacuum treatment of steels of the same composition smelted in similar conditions; due account should be taken of the liquid-steel temperature before treatment, similar sampling methods should be used, and their oxygen and H content determined. It must be remembered that the results in Table III were obtained at different mills and for steels smelted in different aggregates; the table lacks important data which could describe the state of the steel. Nevertheless, as the presented data show, the degree of purification of liquid steel from oxygen and H by vacuum treatment may be considered to be the same and, for all practical purposes, independent of the method of treatment.



11 *Vacuum desulphurization of pig irons*

If we compare the installations used for the implementation of different methods, then it follows from Table III that the vacuum treatment of steel in a ladle is the simplest. The stream degassing method calls for additional equipment such as the intermediate ladle and the second steel pouring ladle. The vacuum-lifter process needs hinge vacuum packing and a mechanism for vertical movement of the chamber. The lifter process and the circulating process require additional appliances for heating the steel and for the conveying gas to treat steel while it is in ciruclation in a vacuum. No less complicated are the appliances for casting relatively small ingots in a vacuum.

The employment of complicated methods and installations may be justified only if it is proved that they are indubitably more advantageous than the methods of vacuum treatment of steel in a ladle. Vacuum treatment of liquid steel in ladles ensures the purification of steel from oxygen and hydrogen without disrupting the production cycle in steelmaking shops.

LIQUID-METAL VACUUM DESULPHURIZATION

When transformer steel was produced in induction vacuum furnaces with magnesite lining, it was found that a decrease of S content in liquid metal was taking place although the heats were conducted without slag. The purification of the metal from S in these conditions was explained by the presence of Si in the iron which ensured an increase in the activity of the S dissolved in the metal and a drop in the oxygen concentration in the solution.[2] The desulphurization of iron containing 3·0 and 3·3%Si when it was held in a vacuum induction furnace with a capacity of 30 lb, with crucibles of magnesium oxide and silica, at a pressure of 4–6 mm Hg was observed by Floridis.[14] It was found during the study of desulphurization of liquid iron in a vacuum that C, Si, and Al accelerate the purification of iron from S and that the kinetics of desulphurization were predetermined by the S diffusion rate in liquid metal.[15]

The results of the determination of desulphurization rate for pig irons of different composition in an induction furnace at a temperature of 1250–1300°C and at a pressure of about $1{\cdot}5.10^{-2}$ mm Hg are presented in Fig.11. Under these conditions a high rate of desulphurization has been achieved for cast iron; at a smaller rate, but in sufficient amount, the basic Bessemer pig iron was purified from S and the vacuum withdrawal of S from basic Bessemer pig iron proceeded at a low rate.[16] The data in Fig.11 should be considered when seeking optimum methods of pig-iron desulphurization outside the blast-furnace. If the high rate of S removal is considered, it is clear that commercial installations may be correctly designed for vacuum desulphurization of pig iron.

TABLE IV Desulphurization of liquid steel by slag-mixture treatment in vacuum-induction furnace

Heat	S content, % before treatment.	after treatment	S removed from metal, %	Pressure in furnace, mm Hg	Temp., °C
1	0·054	0·026	52	28	1560
2	0·048	0·016	67	22	1600
3	0·048	0·017	66	24	1640
4	0·047	0·011	76	22	1610
5	0·040	0·014	65	17	1560
6	0·040	0·007	82	17	...
7	0·076	0·026	67	35	1600

* Duration of treatment 10 min

The removal of S from liquid steel in a vacuum is a slow process despite the presence of elements in the liquid steel which increase the activity of dissolved S. Therefore, it is impossible to hope for a noticeable additional drop in a sulphur content during vacuum treatment. However, in view of the mixing of liquid steel with slag during vacuum treatment there is a possibility of ensuring desulphurization of steel in other processes than those of steelmaking furnaces.

To verify this statement, Chernyakov[17] has made experiments of liquid-steel desulphurization by slag mixtures in a vacuum-induction furnace. Slag mixture consisting of 80% lime and 20% fluorite and heated to 800°C was charged to the surface of liquid steel in a 40-kg induction furnace, and the steel was held for 10 min under a pressure of 17–35 mm Hg. As a result, S content in steel was reduced by 50–80% (Table IV).

The metal charge in the induction furnace was melted in contact with the atmosphere and therefore a certain amount of slag with a high content of iron oxide originated on the surface of liquid metal. This slag was not removed before the slag mixture was charged. Consequently the subsequent vacuum treatment was accompanied by decarbonization of the liquid metal, i.e. in these conditions desulphurization proceeded concurrently with deoxidization of the metal during the vacuum treatment. Table V presents certain data on the change in the metal content during liquid-steel vacuum treatment by this slag mixture, and on the content of separate oxides and S in the slag following the vacuum treatment. These heats were carried out with the object of determining the influence of slag multiplicity upon desulphurization. A high degree of desulphurization may be achieved provided the volume of slag is not above 2% of the liquid metal weight.

These preliminary laboratory tests show that the employment of vacuum opens up new opportunities of desulphurization of liquid steel undergoing vacuum treatment in ladles. The employment of liquid slags with high desulphurization ability is not excluded. The efficiency of such liquid slags and crushed heated

TABLE V Variation of metal composition during vacuum treatment of liquid steel with slag mixture

Heats	Contents in metal, % C before	C after	S before	S after	O before	O after	Content in slag, % CaO	SiO_2	MgO	S	(ΣFe)	Weight of slag/weight of metal, %
1	0·72	0·50	0·030	0·015	0·0094	0·0030	67·7	6·52	11·2	1·20	1·66	2
2	0·88	0·70	0·021	0·007	...	...	72·0	4·00	6·6	0·43	3·00	4
3	0·78	0·73	0·024	0·007	0·0089	0·0043	78·8	3·52	11·4	0·26	1·44	6
4	0·92	0·76	0·019	0·009	0·0100	0·0024	73·0	7·50	8·3	0·26	2·50	8

slag mixtures with the object of desulphurization should be verified in industrial conditions.

PROSPECTS OF VACUUM APPLICATION IN STEELMAKING

The application of vacuum in the steelmaking industry promises new opportunities for considerable improvement in steel quality and in methods of steel production. Although, owing to the small capacity of vacuum induction furnaces, their employment is still restricted, they will nevertheless be widely used for the production of high alloy steels and alloys of special purpose. Such furnaces may be used for the remelting of stainless steel scrap since it is possible to use them not only for remelting stainless steels without noticeable Cr losses, but also possible to produce stainless steel with C content ranging from 0·01 to 0·03% from the scrap of those steels with a higher C content.

In the near future, low-frequency vacuum induction furnaces will be employed for decarbonization of different steels and alloys. Possibly, high-capacity furnaces may be used for pig-iron desulphurization in other than blast-furnace processes.

The capacity of vacuum arc furnaces will grow continuously. Vacuum arc furnaces may be designed to produce ingots weighing several hundred tons.

Millions of tons of vacuum-treated steel will be produced annually. This treatment ensures the obtaining of steel with a low content of non-metallic inclusions. The method is particularly important in the production of steels susceptible to flaking since by means of vacuum treatment the content of H in the liquid steel may be reduced considerably. Vacuum treatment may be combined with desulphurization of steel.

Hence, liquid-steel vacuum treatment, besides improving the quality of steel, ensures the possibility of intensifying the steelmaking processes. The final deoxidization of steel by Si or Al should be carried out generally at the end of vacuum treatment, and thus steel may be produced not only with a low content of non-metallic inclusions but with less expenditure of such deoxidizers as Si and Al.

An additional potential for the improvement of the quality of many steels and alloys and for bringing down metal losses is the pouring of steel in the atmosphere of inert gases. When installations are designed for vacuum casting of ingots, the basic equipment necessary may be utilized for liquid-steel vacuum treatment.

The employment of vacuum begins a new phase in the development of steel production methods in the second half of this century.

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The examination of oxide scales on iron–chromium alloys by X-ray scanning microanalysis

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SYNOPSIS

Oxide scales produced on iron–chromium alloys in steam at 950–1000°C have been examined qualitatively and quantitatively by X-ray scanning microanalysis. This technique clearly reveals two major scale layers, the outer one consisting largely of wüstite, unless air contamination of the steam has occurred, and the inner one containing a rather complex distribution of oxides of iron and chromium. Sometimes a marked chromium maximum and iron minimum is found near the inner scale/outer scale interface but oxidation for a longer period tends to destroy this relatively simple stratification. Chromium depletion is observed in the alloy next to the alloy/scale interface. It is concluded that this new technique enables a rapid, detailed, and reasonably accurate determination of the distribution of elements throughout alloy and scale to be made in oxidation problems of this kind. 1941

INTRODUCTION

NUMEROUS WORKERS have investigated scales produced on iron–chromium alloys and stainless steels in various atmospheres at high temperatures by thermogravimetric measurements, optical and electron microscopy, chemical analysis, X-ray and electron diffraction, and spectrographic analysis. The thin films on alloys that resist serious oxidation are very rich in chromium, consisting largely of Cr_2O_3 together with a little Fe_2O_3[1–3] (which may be in solid solution), or possibly the spinel Fe $Fe_{(2-x)}Cr_xO_4$($0<x<2$) with x nearly 2.[3, 12] With severe scaling, however, a stratified structure is apparent in which various combinations of 'Cr_2O_3', 'Fe $Fe_{(2-x)}$ Cr_xO_4', 'FeO', 'Fe_3O_4', and 'Fe_2O_3' may appear, usually in this order from the alloy to the outer surface depending on the conditions.[1] In certain cases, 'protective' scales formed initially become 'non-protective' on further heating.[2]

There has been considerable disagreement about the structure and thickness of the various layers and their mechanism of growth. This has been aggravated to some extent by lack of standardization of the oxidizing variables and the presence of other alloying and 'tramp' elements in the steels. Oxides of these elements, distributed in the bulk scale in solid solution or as discrete layers or particles, may affect the conductivity and hence the growth rate of the scale and its mechanical properties, in particular its adhesion to the alloy and its plasticity. There is also the possibility of the elements influencing the diffusion rates of iron and chromium in the alloy.

Three problems need to be considered: (*a*) the protectiveness of the initial film, (*b*) the mechanical or chemical 'break-through' of this film to give stratified layers with oxides of iron outside the former protective film, and (*c*) the thickening of both inner and outer layers on further oxidation.

When an iron–chromium alloy is oxidized, preferential oxidation of the chromium leads to a thin layer of 'Cr_2O_3' or possibly 'Fe $Fe_{(2-x)}$ Cr_xO_4' rich in chromium being formed. By analogy with the films obtained on passivation under low-temperature conditions, it seems that the layer is relatively protective because, although it is a reasonable electronic conductor, its ionic conductivity is low.[4] The exact defect structure of Cr_2O_3 is apparently still incompletely understood but it is probably slightly cation deficient.[5–7] It has been suggested[8] that the 'break-through' which may occur after this stage is due to ferrite/austenite phase changes in the underlying alloy but this could apply only to certain alloy compositions. Perhaps a more likely explanation is that iron from the chromium-depleted alloy in contact with the scale tends to enter the Cr_2O_3 lattice, giving initially a Cr_2O_3–Fe_2O_3 solid solution or mixture and later a spinel lattice.[2, 9, 10] This would be an auto-catalytic effect and, once the complete scale was in this form, the transport of iron ions through the film to form an outer layer of iron oxides would be facilitated because of the considerably increased number of cation vacancies. Recent work[11] supports the view that at a later stage the inner scale may become pervious owing probably by cracking, perhaps to phase changes in alloy or oxide,[8, 3] to the accumulation of silica with certain steels,[2, 9, 10] or to stress developed in the layer as it grows.[12] It might tentatively be argued that the inner layer then grows by a mechanism involving the inward passage of

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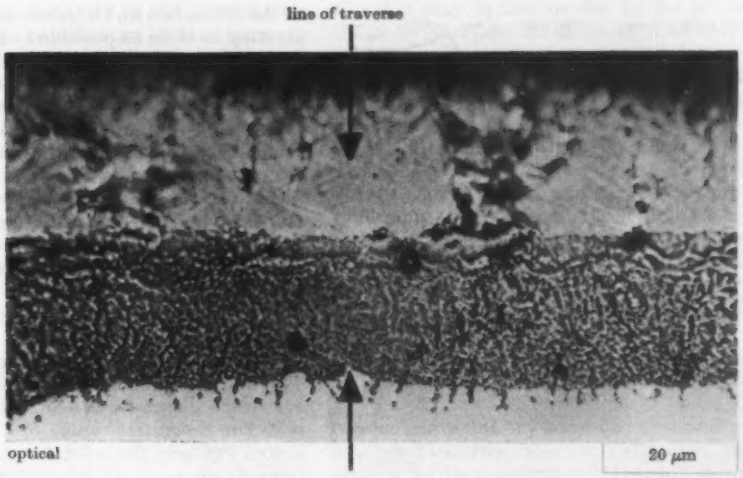


1 *Cross-section through the scale on a pure* Fe–14·4%Cr *alloy oxidized for 10 min* ×1000

oxygen gas and the outer layer by the outward diffusion of iron ions, provided by the dissociation of an oxide of iron into iron and oxygen at the inner scale/outer scale interface.[13, 22]

In the above discussion an attempt has been made to summarize and classify some of the views expressed in the literature on a very complex process. At present no all-embracing theory is available and, as is sometimes pointed out in the original papers, it is possible to raise serious objections to a number of these ideas. For example, in the case of the most likely 'breakthrough' theory it is perhaps difficult to visualize the exact mechanism by which the iron ions pass through the inner scale to form outer layers. Similarly the thermal dissociation theory for oxidation in the later stages requires justification. Evidently a further understanding of the defect structures and mechanical properties of the oxide phases grown on the alloys is required. A more detailed discussion of the present state of knowledge is beyond the scope of this paper.

A knowledge of the distribution of alloying and 'tramp' elements throughout the scale and the adjoining alloy at various stages of oxidation would assist considerably in formulating a definitive growth mechanism. The introduction of the X-ray scanning microanalyser[14–16] provides a means of obtaining such information. An instrument of this type, developed at the Tube Investments Research Laboratories, was used in this investigation.[17]

From a cross-section through the oxide and adjoining alloy several types of information are obtainable.

(i) A quantitative analysis of any selected region of about 1 μm diameter in the surface of the oxide or alloy using a static electron probe.[18] This technique of electron probe microanalysis has a possible accuracy of ±1% for elements of atomic number greater than 12.

(ii) A semi-quantitative display of the distribution of an element along a chosen line on the specimen can be obtained by using one of the display screens to monitor the X-ray intensity as the beam is scanned slowly along the line. This facility may be regarded as providing an intermediate stage between the point analysis and the X-ray image obtained as described below.

(iii) With the probe scanning a square region on the specimen X-ray images can be obtained selecting the characteristic radiations of the various alloy constituents. These reveal the distribution of each constituent over the field of interest, which can be any size from 500 μm square to 50 μm square depending on the magnification required.

(iv) An image of the surface can also be formed in terms of its capacity for back-scattering electrons. This image not only shows contrast due to differences in atomic number but also reveals the surface topography in a manner very similar to an optical image taken in oblique illumination. It also has a greater depth of focus (about 60 μm) than an optical image taken at the same magnification and is therefore particularly useful for examining rough surfaces and edges.

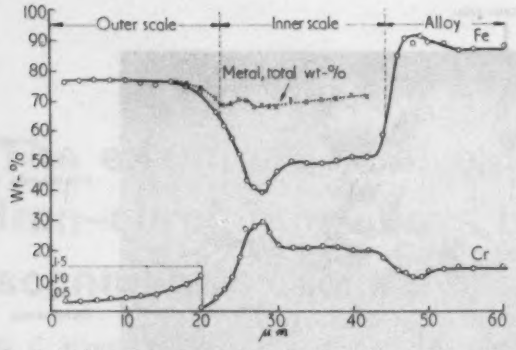
X-ray microanalysis has been used for a number of metallurgical investigations, those most closely allied to the present study being examinations of oxide scales on certain steels,[19] of sub-scales,[20] and of spinel grains.[21]

SPECIMEN PREPARATION

In the present study the technique was applied to the analysis of oxide layers formed on two iron–chromium alloys: (*a*) pure iron–14·4 wt-% chromium strips 2·5 cm ×0·5 cm ×0·0375 cm. This alloy was prepared[1] from vacuum-melted electrolytic iron and hydrogen-treated electrolytic chromium by melting in an inert arc furnace, followed by homogenizing treatment at 1000°C in a hydrogen atmosphere and finally hot-rolling at 600°C; and (*b*) commercial iron–chromium alloy strips, 2·5 cm ×0·5 cm ×0·15 cm, of composition, wt-%:

C	Si	Mn	S	P	Cr	Ni
0·23	0·27	0·26	0·016	0·033	13·36	0·41

This material was supplied in the fully softened condition (soaked for 2 h at 850°C, air cooled, heat-treated again at 750°C for 3 h, and finally air cooled).



2 *Point by point microanalysis for chromium and iron along the line of traverse shown in Fig.1*

The specimens were abraded on 180-grade silicon carbide paper, carefully degreased with acetone, and heated in steam (probably contaminated by a little air) at 950–1000°C for periods of 10, 30, and 300 min. After cooling, they were mounted in a cold-setting resin and cross-sections were prepared using 180-, 320-, and 400-grade silicon carbide papers lubricated with water, followed by 6 μm, 1 μm, and $\frac{1}{4}$ μm diamond suspension and finally alumina slurry on a polishing wheel.

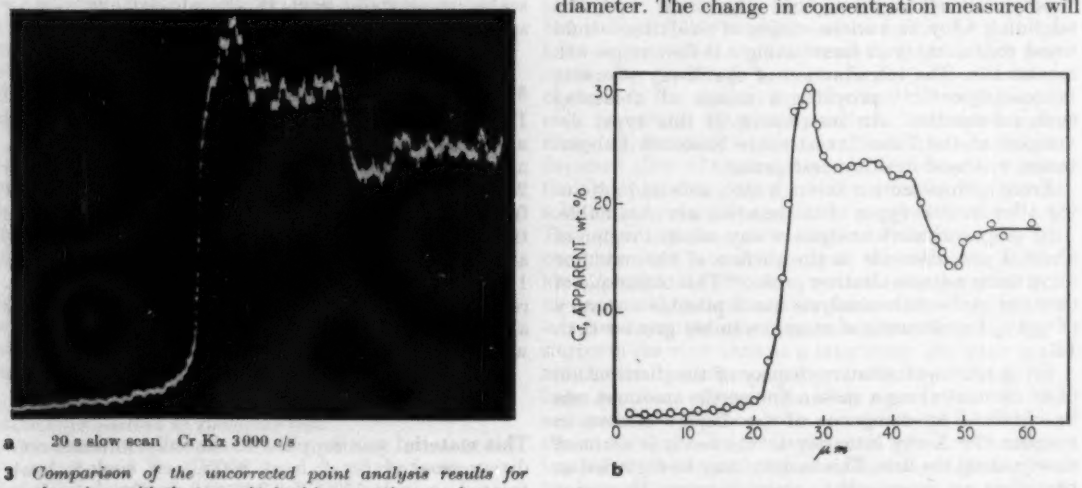
EXPERIMENTAL RESULTS AND INTERPRETATION

Optical examination revealed two main layers of scale, of about equal thickness in all cases and often separated by a cavity. At present it is not entirely clear whether such cavities are introduced during growth, cooling, or polishing. The results of micro-analysis of typical specimens are described below.

Figure 1 is an optical image at ×1000 magnification of a cross-section through the scale on a specimen of the pure alloy oxidized for 10 min. The two layers of scale can be clearly seen. Using the microanalyser as a static probe instrument a series of 35 quantitative analyses was made at 2-μm and occasionally 1-μm intervals along a line 60 μm long in a direction normal to the scale/alloy interface. Measurements were made of the chromium and iron concentrations at each point, starting as close as possible to the outer surface of the scale. The results, after correction for absorption and fluorescence effects, are probably accurate to ±1% and are presented in Fig.2, the positions of the interfaces being obtained by inspection of the electron image. In Fig.3 the variation of chromium across the scale is compared with a trace photographed off the display screen while the probe scanned slowly across the field and Cr Kα radiation was being recorded. Some statistical fluctuation is evident in the trace but its overall similarity to the quantitative result indicates that this facility can be very useful in making preliminary observations and in selecting the axis for a quantitative traverse.

The iron concentration in the outer layer of scale is 77·0 wt-%, this value being reasonably constant within 1% over a distance of 14 μm. This is in good agreement with the theoretical value of 77·7 wt-% for stoichiometric FeO and also with the values of 77·0–77·5 wt-% recently obtained for wüstite on various steels by the technique of electron probe microanalysis.[19] It is a little high when compared with the figures of 75·6–76·5 wt-% and 75·6–76·9 wt-% given by earlier workers[22, 23] using other methods. Readings could not be made close enough to the outer scale/atmosphere interface for any possible thin magnetite layer to be detected. There was apparently no oxygen gradient in the wüstite layer; if it existed it was too small to be detected. A small quantity of chromium (about 0·3 wt-%) was also found in the outer layer. This appeared to rise to 5 wt-% as the inner scale/outer scale interface was approached, but the increase was probably partly due to the fluorescent excitation of chromium in the inner scale by Fe Kα radiation from the outer scale.

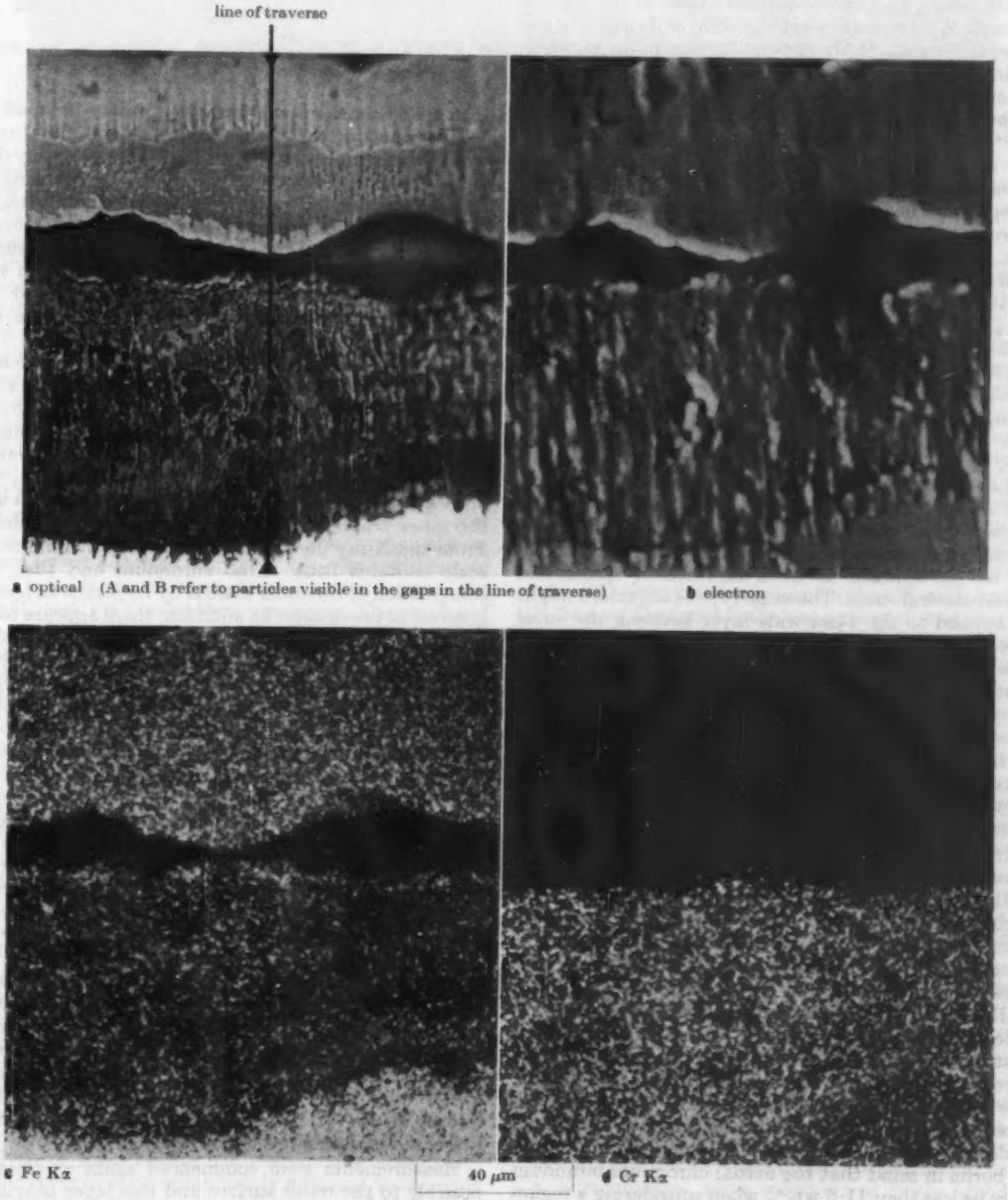
At this point it should be noted that the concentration gradient measured by this technique at an interface is affected by the finite size of the probe or strictly speaking the X-ray source, which is slightly larger due to lateral diffusion of electrons in the specimen. For example, even when traversing a perfectly sharp, undiffused interface normal to the surface some portion of the probe will be in contact with this interface over a distance at least equal to the probe diameter. The change in concentration measured will



a 20 s slow scan Cr Kα 3000 c/s

3 *Comparison of the uncorrected point analysis results for chromium with the trace obtained by a continuous slow scan*

thus be spread over this distance. In the present case the scale/alloy interface, as indicated by the change in iron content, appears to occupy a distance of about 3 μm. This is certainly partly due to the finite size of the X-ray source and possibly to the interface not being normal to the axis of traverse at this particular point. On the other hand the apparent inner scale/outer scale interface as indicated by the variation in iron concentration is spread over some 7–8 μm. It can be expected that the size of the X-ray source in the oxide is slightly greater than in the alloy, due to the increased lateral diffusion of electrons in the less dense material, but even so this spread seems rather excessive and may in fact be due to the presence of more than one interface. Some support for this view can be gained by adding the two curves together and obtaining thus the total wt-% metal in the scale at each point. It can be seen that the resulting curve changes direction markedly at a point corresponding closely to the position of the inner scale/outer scale interface. There then appears to be a 4-μm wide layer, extending nearly as far as the chromium maximum and iron minimum, over which the total wt-% of metals increases slightly (by ~2%). At the position of the chromium maximum the total wt-% of metal drops to a minimum and appears from then on to exhibit a

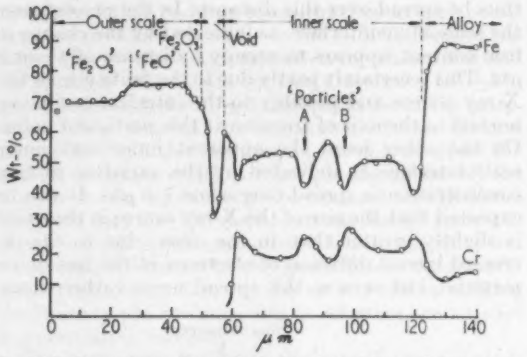

line of traverse
a optical (A and B refer to particles visible in the gaps in the line of traverse)
b electron
c Fe Kα
40 μm
d Cr Kα

4 *Cross-section through the scale on a pure* Fe–14·4%Cr *alloy oxidized for 30 min* ×600

significant upward trend throughout the rest of the inner scale layer as the scale/alloy interface is approached. The oxygen content of the main inner scale in fact appears to decrease from outside to inside by about 3%, a figure which might reasonably be expected. There is some indication of a layer about 4 μm thick between the outer scale and the main inner scale in the optical photograph and it may therefore be that the iron concentration gradient here is a reflection of two interfaces and not one.

The total at-% metal curve has the same general shape as the corresponding wt-% curve. Before attempting an interpretation of these results it is worth noting that rhombohedral oxides of the general formula M_2O_3 contain 40 at-% metal and spinels of the general formula M_3O_4 42·9 at-%, assuming stoichiometry. In addition, it is generally held that 'FeO' and the spinel 'Fe $Fe_{(2-x)}Cr_xO_4$' are cation deficient, 'Cr_2O_3' slightly cation deficient, and 'Fe_2O_3' anion deficient.[5–7, 22–24] Always bearing in mind the experimental accuracy of the readings, it seems possible to draw some conclusions about the structure of the inner scale. The composition near the alloy/inner scale interface is best represented by the formula $Fe_{2\cdot10}Cr_{0\cdot91}O_4$ or $(Fe, Cr)_{3\cdot01}O_4$ which is in very good agreement with the stoichiometric value of $(Fe, Cr)_3O_4$. At the chromium maximum, however, the most likely formula $Fe_{1\cdot09}Cr_{0\cdot88}O_3$ or $(Fe, Cr)_{1\cdot97}O_3$ is near the stoichiometric value of $(Fe, Cr)_2O_3$. This composition could indicate anything from a homogeneous solid solution to a finely divided heterogeneous mixture of 'Fe_2O_3' and 'Cr_2O_3'. Compositions 1 μm and 2 μm to the right of the chromium maximum are equivalent to $Fe_{1\cdot16}Cr_{0\cdot76}O_3$ or $(Fe, Cr)_{1\cdot92}O_3$ and $Fe_{1\cdot27}Cr_{0\cdot65}O_3$ or $(Fe, Cr)_{1\cdot92}O_3$ respectively. The metal content here is curiously low but this may be partly due to experimental error. The oxide in the middle of the inner scale, where the chromium and iron contents are respectively 21 and 49 wt-%, appears to be a mixture of spinel and rhombohedral oxide. The same type of argument might be applied to the 4-μm wide layer between the outer layer and the main inner layer but any conclusions would be difficult to justify. The general conclusion is that the proportion of spinel is greatest near the alloy/scale interface, which agrees in principle with the most likely theory of 'break-through' mentioned earlier.[3] It is tempting to propose that the chromium maximum represents the position of the original protective 'Cr_2O_3' layer, now in a somewhat diluted form.

In the alloy itself a depletion in chromium was observed in a 5-μm wide layer immediately adjacent to the scale. This result is to be expected because of the high values reported for the activation energy of interdiffusion of chromium and iron.[25] The chromium content here falls to a minimum of 11·5 wt-% and rises again to a value of 14·3 wt-% in the bulk material which is in very good agreement with the chemically determined value of 14·4 wt-%. It might be expected that the alloy/scale interface would occur at the chromium minimum. That this is not the case may be due in part to the uncertainty of the position of the interface (±1 μm) and also to the presence of the subscale observable in the optical micrograph. It should be borne in mind that the actual chromium minimum may be less than 11·5 wt-% when considering a region less than the size of the probe. The enrichment in iron



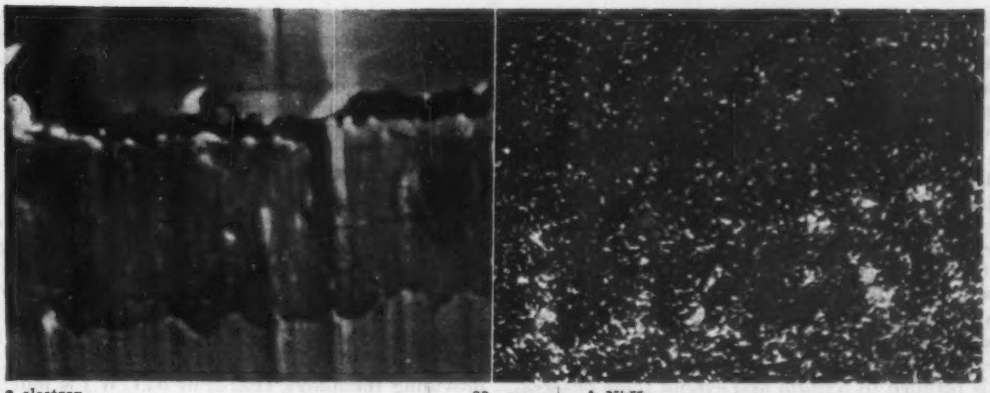
5 *Point by point microanalysis for chromium and iron along the line of traverse shown in Fig.4*

accompanying the depletion in chromium is found to be disproportionately large, giving a total metal content in this region of 102·5 wt-%. This is probably due to topographical effects at the interface resulting in Fe Kα radiation emerging from the specimen without being subjected to the expected amount of absorption. The absorption correction appropriate to the measured chromium content is therefore an over-correction and the value for the iron concentration obtained by applying it in this uncertain situation must be expected to be slightly high.

When the oxidation time was increased from 10 min to 30 min the structure of the scale layers became even more complex. In Fig.4 optical and electron images of such a specimen may be compared with X-ray images taken selecting Fe Kα and Cr Kα radiation. A crack has now appeared between the two scale layers, the outer scale appears to consist of several sub-layers and the inner scale contains a number of dark particles. From the X-ray images it is again clear that the outer scale contains little or no chromium and that the composition of the inner scale is by no means as homogeneous as previously. In addition, there appears to be a region at the base of the inner scale which is relatively depleted in iron and enriched in chromium and the same can perhaps be said for the largest of the dark particles. The grainy nature of these images is due to the fact that they are formed from a limited number of X-ray quanta. This effect could be reduced by increasing the exposure time and hence the number of quanta recorded. In practice it is usual to strike a balance, bearing in mind the desirability of short exposure times on the one hand, and the need to produce an image showing sufficient contrast to reveal the compositional variations that exist on the other. If these variations are small then before they become apparent in the image a correspondingly larger number of quanta must be recorded.

As before, a series of quantitative measurements was made along a line normal to the scale/alloy interface and the results are presented in Fig.5. The 'resolution' of this traverse was less than the previous one as, due to the increased thickness of the oxide, measurements were made only every 4 μm with occasional interpolations at 2-μm intervals. The information presented is therefore slightly less detailed.

Measurements were commenced again as close as possible to the outer surface and this layer proves to contain 70·7 wt-% iron, which corresponds most



6 *Cross-section through the scale on a commercial* Fe–Cr *alloy oxidized for 30 min* ×1000

closely to the stoichiometric value for Fe_2O_3 of 69·9 wt-%. The value obtained for the centre section is 75·6 wt-% iron, which lies at the lower end of the range of compositions attributed to 'FeO'.[22, 23] It should be noted, however, that in the optical image there is some evidence of precipitation in this section (probably magnetite) on a scale well below the resolution of the probe and this may be affecting the results. The inmost section of the outer scale also appears to be 'Fe_2O_3' but it was difficult to be absolutely certain in the case of a layer so thin. The presence of this layer indicates that the atmosphere penetrated into the gap and oxidized the underside of the outer scale. The gap also disrupted the general outward diffusion of iron and thus allowed the outer layer to be oxidized more severely than with the previous specimen. It also seems clear that contamination of the furnace atmosphere by air occurred and there was some evidence of the 'Fe_3O_4' layers which might be expected between the 'Fe_2O_3' and 'FeO' under these conditions. The spacing of the analysis points, however, was too great for their existence to be definitely confirmed. It is surprising to find so much 'Fe_2O_3' but the measurements were carefully checked and reproducible results obtained. The position of the void as related to the iron concentration appears to correlate well with the position of the interface marked on Fig.4. Analysis values within the crack have no real meaning as a large part of the X-ray emission was absorbed under these conditions.

The structure of the inner scale is even more complex in this case and a linear traverse is thus not a suitable method for investigating its composition. Of the chromium maxima visible in Fig.5, only the one closest to the alloy/scale interface appears in the X-ray and optical images to be a *bona fide* layer. The others appear to correspond to the darker 'particles' in the scale and in this case the probe may well have been near the edge of the 'particle'. In the case of the 'particle' A, for example, it was found that the true chromium maximum in that region lay a little to one side of the axis of traverse and hence the lower value recorded may be a result of the probe not being entirely absorbed within the particle. No detailed analysis of these results will therefore be attempted. In the layer of alloy immediately adjacent to the scale a depletion of chromium to a minimum of 12·0 wt-% was again observed (not necessarily the true minimum) and the value in the bulk of the alloy was once more determined as 14·3 wt-%.

A commercial iron–chromium alloy specimen oxidized for 30 min was also examined but not in such great detail as the specimens previously described. The distribution of iron and chromium throughout the cross-section was found to be similar to that observed in the case of the pure alloy although the overall oxidation rate was rather less. The same area was then scanned successively for nickel, manganese, and silicon, but only the first of these showed segregation. In the case of manganese this is hardly surprising because it can enter into spinel formation, but the absence of silica is noteworthy as it has been observed at or near the alloy/scale interface of some steels by certain workers.[2, 9, 10] If any particle or layer of silica was present its size was well below the resolution of the probe. The segregation of nickel in the sub-scale and at the base of the inner scale was expected, but curious 'pillars' of nickel-rich material were found to extend well into the inner scale, did not correlate with any feature of the optical image, and are not easily explained. An electron image and a nickel X-ray image revealing this distribution are reproduced in Fig.6.

CONCLUSIONS

1. The results obtained are in general agreement with some of the extensive literature on the oxidation of iron–chromium alloys and the following conclusions may be drawn.

(*a*) Under the oxidizing conditions employed the oxide film is 'non-protective' and two main scale layers of approximately equal thickness, sometimes separated by a cavity, are observed.

(*b*) The outer layer is largely 'FeO' containing a very small proportion of chromium. Where air contamination of the steam atmosphere has occurred, however, layers of 'Fe_2O_3' and possibly 'Fe_3O_4' are apparently also detected.

(*c*) The inner layer consists of chromium and iron oxides. For the pure alloy heated for 10 min, a traverse from the inner scale/outer scale interface to the alloy shows a change in oxide composition from a homogeneous solid solution or finely divided heterogeneous mixture of 'Fe_2O_3' and 'Cr_2O_3' to the

spinel '$(Fe, Cr)_3O_4$'. A chromium maximum and an iron minimum are observed near the inner scale/outer scale interface. In the case of the pure alloy heated for 30 min the inner scale is even more complex and appears to contain discrete 'particles' rather than a layer structure.

(*d*) The alloy in contact with the oxide is depleted with respect to chromium from 14·4 wt-% to at least 11·5 wt-%.

(*e*) The commercial alloy heated for 30 min shows the same general distribution of iron and chromium but no segregation of manganese and silicon is observed. This indicates that bulk silica does not play an important part in determining the oxidation resistance of this particular alloy. A curious segregation of nickel occurs at the alloy/scale interface.

It is planned to confirm and extend these observations on specimens prepared under more precisely defined conditions. In particular, it should be of interest to examine specimens oxidized for shorter periods or under less severe conditions than those described in the present paper in an attempt to trace the 'breakthrough' of the initial 'protective' 'Cr_2O_3' film.

2. It is apparent that much detailed information about oxide scales can be obtained with the aid of the X-ray microanalyser. One object of this paper has been to illustrate the possibilities of the technique. In particular, it enables a general survey of the cross-section to be made very rapidly and the tedious sampling required in certain other methods is avoided. Although the quantitative measurements have a limited accuracy, again great speed and exact positioning in the scale are possible. Interpretation of the information should initially be made with caution until more experience has been gained but the results of such experiments must be of considerable assistance in formulating a mechanism for the oxidation process. In certain cases it may be desirable to check some of the information by comparing it with data obtained by more conventional techniques. For example, in the present case it would be useful to obtain the structures of the various oxides present by X-ray methods.

The limitations of the technique should always be borne in mind. The resolution is limited by the lateral diffusion of electrons to approximately 1 μm which makes it impossible to examine layers thinner than this directly from cross-sections. It might be possible to overcome this to some extent by using suitable taper sections but it would be necessary to ensure that the electron probe did not penetrate beyond the layer of interest. In the case of light elements (atomic number < 20) the accelerating voltage can often be reduced with advantage to, say, 15 kV. Under these conditions sufficient excitation of the K radiation is still obtained but the background of continuous radiation and also the penetration of electrons into the specimen are both considerably reduced. In addition, concentrations of an element less than 0·1 wt-% are difficult to detect, which is unfortunate as they may have considerable influence on the defect structure of the bulk oxide. It is not possible at present to analyse for carbon, oxygen, and nitrogen.

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English bloomeries (1329–1589)

R. A. Mott, D.Sc., F.R.I.C., F.Inst.F.

SYNOPSIS

An account is given of the annual make and costs of production of blooms of iron at Tudeley, Kent (1329–1354) and Kyrkeknott (or Byrkeknott), Weardale (1409), together with details of certain other bloomeries, particularly Rievaulx, North Riding, and Farnley and Oxspring, West Riding, in the period concerned. A translation of the Latin records for Kyrkeknott is given in an Appendix. It is argued that the water-wheel operated power hammer was in use at Kyrkeknott (1409) and at the 'oliver' at Creskeld, West Riding (1352), nearly 150 years before the date at which Schubert considers it was first used.*

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BEFORE THE CHARCOAL BLAST-FURNACE and its associated finery (forge) were introduced by French workmen into England in Sussex at the end of the 15th century, iron had been made in Britain in bloomeries for 2000 years. In the most flourishing period of the Sussex iron industry, namely the 25 years which ended with the defeat of the Armada, the charcoal blast-furnace and forge had been introduced into the counties of Stafford, Salop, Monmouth, Glamorgan, York, and Derby, and the bloomery process, though it survived in isolated units, had reached the end of its career.

In the last 200 years of its long life in Britain the bloomery process underwent a remarkable change. The daily output of the Tudeley bloomery, Kent (1329–54), was a bloom of about 30 lb. That of Kyrkeknott,* Weardale (1408–9), was 195 lb, and those made during the 16th century at Rievaulx, Farnley, Emley, and Oxspring (Yorks.) were, according to Schubert,[1] all of about 2 cwt in weight. Kyrkeknott therefore represents the earliest known bloomery in this country in which the scale of operations had increased sixfold as compared with earlier practice. Kyrkeknott was the first British bloomery in which it is known for certain that there was a water-wheel, so that the increase in the scale of operation can probably be ascribed to this. Schubert in his book argues, however, that at Kyrkeknott the water-wheel was used only to operate the bellows and that a foot-operated 'oliver' or hammer was used, the power or water-wheel operated forge not being introduced until the charcoal furnace with its adjacent finery or forge was started in Ashdown Forest, Sussex, in the closing years of the 15th century.

In the Forest of Dean the bellows of a charcoal blast-furnace in 1635 were 18 ft long and 4 ft wide and were operated by a water-wheel 22 ft in diameter, the furnace making about 2½ tons of iron per day. For the Kyrkeknott bloomery making 0·1 ton/day the scale was only one twenty-fifth of this and the bellows would be much smaller, possibly only 4 ft × 2 ft. Such bellows, in pairs, could easily be operated by treadles, as is shown in Fig.1 for a Swedish Osmund (bloomery) furnace of 1734.

On the other hand, the value of a water-wheel to operate a powerful hammer to flatten the bloom, so that it could more easily be cut into the 'pieces' in which form it was finally sold, is more obvious. It is this usage of a power hammer which was first emphasized in its early use in France. It appears probable to the writer that this function of the water-wheel was introduced into England not later than 1350 and that the Kyrkeknott bloomery of 1408 was an example of such usage. If this be true the water-wheel operated hammer was in use in this country 150 years before Schubert considers to be the case and the view contrary to Schubert's is worthy of argument.

In France a *moulin à fer* (iron mill) was in use by the Templars at Templiers, southern Champagne in 1203, the text[2] referring to repairs to hammers (*marteaux*). In the same region in 1249 the use of a *moulin à fer* is described *quoddam molendium . . . ad quod ferramenta molentum*,[2] which may be interpreted as a mill at which a tool shod with iron was used. Any doubt of the meaning of 'iron mill' is dispersed by a lease in 1283 to build *une mouline à battre fer*[2] (a mill to beat iron) or the contract in 1323 at Briey (Metz) for a *forge hydraulique* or a *forge faisant fer par eaue*[2] (a forge making iron by water). The phrase *forges à eaux* was used in 1345 in the county of Namur.[2] In 1339 and 1346 the expression *martinet* (tilt hammer) was used to describe a forge of which the heavy hammer was the outstanding feature. All these entries are for dates before the *haut fourneau* (high or blast-furnace) was developed and therefore referred to bloomeries.

The water-wheel operated hammer was known in Bohemia and Lower Silesia in the 11th–12th centuries.[3] Moreover, the water-wheel had been applied to stampers to break ore by 1135,[3] to blowing furnaces by 1213 and to wire drawing by the first half of the 14th century. Consequently, the ironworks moved to the streams, which were most prolific in the mountainous areas. Ress[4] has given a record of ironworks in Oberpfalz (Bavaria) in 1387 where the hammers were known as *Schienhammer* (string hammer) and *Blechhammer* (plate hammer) and were spread along the streams near Bayreuth. From the bloom hearth a bloom of 175 lb was taken to the

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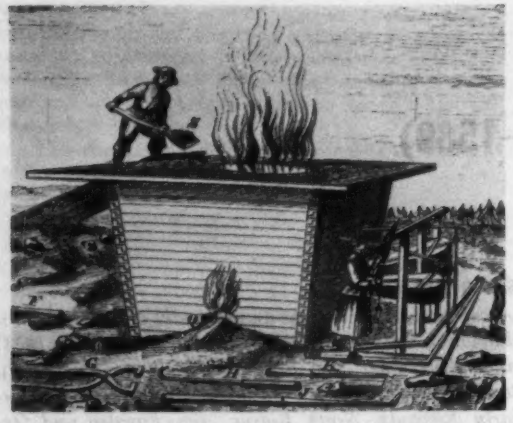
*This has previously been referred to, incorrectly, as Byrkeknott; *see* Appendix 1, note 3.



1 *Treadles of bellows for Swedish Osmund bloomery 1734. The woman is using a distaff.* (J. PERCY: 'Metallurgy', *Iron Steel*, 1864, Fig.28 (based on E. Swedenborg, 'de ferro', 1734, Leipzig))

string hearth, after which it was reduced by hammering to plate in pieces of about 10 lb. A portion was further treated to produce sheet.

During the four centuries until the end of the 100 Years War (1337–1453) the English Kings controlled most of the western half of modern France and encouraged the making of iron and steel.[2] When Henry Percy bought Alnwick from the Bishop of Durham in 1309 and the Percys began their long connexion with Northumberland, his ancestors had had their chief seat for six generations at Spofforth Castle, in the West Riding. This First Baron Percy of Alnwick and his son and grandson saw service in Gascony and Guienne, the provinces in the extreme south-west of France. Spofforth is just south of the ancient forest of Knaresborough, near Kirkby Overblow and Harewood, areas which were all very active in ironmaking in the century before 1352.[5] In that year Creskeld, and in 1408 Black Moor (respectively 4 miles west and south of Harewood), were recorded as sites of bloomeries of a new type. Black Moor was formerly in Harewood Manor. Both places were probably under Percy influence, and would have been likely to introduce the technical advances which the Percy armourers had seen in France.

At Creskeld in 1352 Sir Richard de Goldesborough demised *deuz Olyveres contenaunz vynt quatre blome* (two olivers with a capacity of 24 blooms), together with wood and ore, for a weekly rent of 14*d*. This rent may be compared with that of the Tudeley bloomery making six blooms per week and rented in 1354 for 13*s*. 4*d*. a year (about 3*d*./week) and in 1334 for one-twentieth of this. The weekly payments at Creskeld suggest that the capacity of 24 blooms was per week, i.e. 2 blooms/day per oliver.

This lease is the first known mention of an oliver. The next is for 1375 when Sir John de Neville let to John del Loge *un olyuer de X bloomes en la symaigne* (an oliver of 10 blooms/week) at Brancepeth, Weardale, paying a rent of 30 pieces of iron per week for 40 weeks in the year. Accepting Salzman's interpretation of a 'piece' as 2 lb, and the contemporary sale price of iron as £4/ton, this is equivalent to 2*s*./week, a formidable amount.

Before building the Kyrkeknott bloomery with its water-wheel in 1408, the bloomer with a companion went to 'Blackmore' to see a similar forge the better to build the new one, a round journey which took 3½ days on horseback; it may be assumed that there was a water-wheel operated bloomery at Black Moor (4 miles from Creskeld).

Schubert has concluded that the oliver, like its 18th–19th century counterpart used by the nailers, was a treadle-operated hammer; the one of 1770 he illustrates can be calculated to have had a 60-lb head and a handle or helve 5 ft long. That illustrated by Plot[6] (1686) was of similar scale, but it is probable that one hammer at Kyrkeknott was of at least 100 lb. A helve hammer used for making armour in 1380 had a helve 8 ft long,[7] a length possible only with water-wheel operation. When a smith received a 30 lb bloom it was roughly V-shaped, owing to the effect of the blast pipe, and was readily cut into two pieces. For a 15-lb piece a hammer of the same weight, which is probably as heavy as a man can regularly wield, would be suitable for shaping this cube (effectively 3·8in). For a bloom of 2 cwt, even after cutting in two, a 60-lb hammer would be small for shaping a 7-in (effective) cube but one with a head of 100 lb, with the usual wooden spring above the helve to give extra impetus, would be much more serviceable as well as leaving all limbs free. It is fair to conclude therefore that the oliver as applied to the bloomeries of 1352 (Creskeld) and 1375 (Brancepeth) could be expected to be water-wheel operated to make possible a bigger production and payment of a higher rent. If the Creskeld production was 24 blooms per week and the bloom only 30 lb, the production would be four times that at Tudeley and would enable a rent about 5 times that of Tudeley to be paid. At Brancepeth the rent was nearly twice that at Creskeld, which suggests that the 10 blooms per week must have been still bigger.

Such a mechanical development was more likely to occur in the West Riding than in the south for, in addition to a more widely developed iron industry, there were fulling mills which were advanced examples of the use of mechanical advantage. When Domesday Book was compiled there were 10000 cornmills operated by water-wheels but these were probably small horizontal (Nordic) wheels; the vertical wheel had to be designed to develop greater power. The fulling mill (a walkmill, because it replaced the 'walkers' who trod the cloth to consolidate it) was a hammer mill with a hammer falling through an arc of 90°. By the 14th century there were at least 63 fulling mills in England, 30 of these in the West Riding and the Lake District.[8]

Salzman has stated 'I had independently of the O.E.D. come to the conclusion that they (olivers) were tilt hammers and had conjecturally associated them with the Paladin Oliver famed for his shrewd blows'. This is quoted in an article on the Creskeld iron workings[9] in which the following shows that an oliver at Farnley (3 miles from Creskeld) had a dam and water course in 1582.

> May 1582, Farnley Smythe
> Paid to the Smetheman coursing and trimming the 'Olyver' and mending the great dame 14*s*. 4*d*.
> Item for theaking [thatching] the olyver

There are other records quoted for Farnley smithy for 1567–8. In an unspecified period ending 11 October

TABLE I Cost of charcoal at Tudeley

Year	Campaign	Weeks of blowing	Amount delivered (tens)	(price/ten) s. d.	Carriage (per ten)	(per load) d.	Price per load delivered,** d.	Loads used per bloom††
1329–30	1 Nov.–29 Sept.	(28)	36	3 6	...‡	...	3·50	2·2
1332	1 Nov.–29 Sept.	(32)	41	3 7	4	0·33	3·58	2·2
1333	1 Nov.–29 Sept.	(33)	34	...*	4	0·33	3·50	2·15
			7½	3 6	...‡	...	...	...
			Dozens–loads	Price/dozen	Per dozen			
1333–4	1 Nov.–29 Sept.	16	20	3 10	...‡	...	3·28	2·5
1350–1	16 Oct.–30 July	36	16	7 3	7	0·5	6·91	2·2
			24	8 7†	7	0·5		
1352	14 Jan.–31 July	21	22–11	8 7	7	0·5	7·36	2·03
1353	Sept. –Nov.	7	5–8	9 2	14	1·0	7·86	2·6
1354	–29 Sept.	25	14–12	8 7	7	0·5	7·41	2·5
			8–7	9 2	14	1·0		
			2–5	7 4	...‡	...		

* No charge made for wood from the Lord's forest; price of other delivery assumed
†From the Lord's forest
‡Delivered price, carriage not stated
**Assuming the ten=12 loads, the dozen being known to be 14 loads
††From 1352 onward some charcoal was surplus at the end of the campaign; the charcoal actually consumed is used in the calculation

1567, 10 blooms and 4 pieces had been made which later in the month had been converted to 19 dozen and 3 pieces sold for £7 16*s.* 0*d.* (i.e. 1 bloom cut into 24 pieces each worth 8*d.*), and there is another for February 1568 when 7 blooms each worth 16*s.* were sold. At that time English bar iron was selling at £10/ton compared with only £6/ton in 1542 when finished iron pieces were sold at Rievaulx bloomery for £4/ton. If the Farnley pieces of 1568 were worth £8/ton, a bloom would weigh 2 cwt and the 'piece' 9 lb compared with 24 lb at Rievaulx. It is clear that the Farnley bloom was similar to that at Kyrkeknott and that the oliver was water-wheel operated.

A final reference may be made to Creskeld, for which a deed[10] of 1395 shows that there was still a bloomery there, and a water-course and a walkmill were specifically mentioned. The annual rents were 16*s.* 8*d.* for the water-course, 16*s.* for a meadow, and for the wood consumed, 8*d.* for every 12 blooms. For the 24 blooms per week of the 1352 lease this is equivalent to 1*s.* 8*d.*/week, not dissimilar to the rent of 1352, which suggests that the Creskeld oliver of 1352 was water-wheel operated. The term 'oliver' in the 14th–16th centuries, associated with a bloomery, may therefore be taken to mean a water-wheel operated hammer. When what was known as a nailer's oliver in the 19th century was first described, it was not so-called; Plot[6] (1686) and Thoresby[11] (1702) both referred to it as an 'engine'.

THE TUDELEY BLOOMERY

It is desirable to give a tabular record of the operations of the Tudeley bloomery for the full record, in Latin,[12] is not in regular form, being compiled by four separate recorders; moreover, certain changes in practice make Straker's summary[13] of costs, hitherto the best available, incorrect. The simplest presentation is obtained by reducing the costs of ore, charcoal, and manufacture to a cost per bloom. For comparison of different years a solution must be found for the relationship between the two units used to measure the charcoal, which was supplied from the forest of the Lord of the Manor, Elizabeth de Burgh, Lord of Clare and South Frith, where the bloomery was built. The records for 1329–30, 1332, and 1333 have as the unit for the charcoal a *decenna* (ten) and those for 1333–4 a *duodena* (dozen), a dozen being defined as 14 *summagia* (pack-horse loads). In the later records for 1350–4 the charcoal is also delivered in dozens of 14 loads. The pack-horse load is relatively easy to estimate as being equal to one quarter of 8 bushels, a bushel of that period being 1·00 ft³, so that the load was an awkward (8 ft³) but light (120 lb) load.[14] The reason for making a 'dozen' equal to 14 loads was to allow for the settling during transport so that there would be on arrival 12 quarters in a dozen. In the 16th century the practice was that a dozen (12 quarters each of 8 bushels, 1 bushel=1·24 ft³) was not to be less than 10½ quarters on arrival.[15] The decenna of 1333 cost 3*s.* 6*d.* delivered; the dozen of 1333–4 cost 3*s.* 10*d.* delivered so that clearly a decenna and a duodena are not of very dissimilar measure. Guiseppi, who notes this, confuses the picture by filling in an unreadable gap as follows (bracketed) for 1332 *qualibit decena continenti xxiiij* [*quarteria*] which must be incorrect. Probably the indecipherable word is 'bole', which was half a quarter, and the ten was 12 quarters or loads, which would be equal to a 'ten' on arrival. This assumption has been made in Table I in calculating loads of charcoal per bloom and gives a reasonable answer, though 13 loads to a ten would be even better. On the other hand 12 loads per ten makes the transport cost per load ½*d.* in the earlier years; since in later years the simple units were ½*d.* and 1*d.* per load, this supports the assumption of 12 loads to a ten.

The cost of ore is given per 100 blooms and this is reduced to the cost per bloom. In certain years the ore supplied remained for use in subsequent years but ore was delivered each year so that any variation in cost can be traced. A carriage charge for ore and one for roasting are given, the carriage charge increasing by 50% after the Black Death in 1349 which affected all prices but that for roasting. Dead wood was used for roasting ore.

The bloomery was operated by four blowers, namely the master blower and the second, third, and fourth blowers. It must not be assumed that this represented their sole occupation. There was only one hearth, the bloom (blowing) hearth, operated by a pair of bellows, possibly hand-operated with one man per bellows. They received a combined payment which was 5½*d.* per bloom in 1329–30 and in 1332–4 2¼*d.* per bloom

TABLE II Costs of operation per bloom at Tudeley

Year	Blooms made campaign	week*	Ore carriage d.	total† d.	Charcoal, total d.	Blowing, total d.	Other expenses,‡ d.	Total expenses,** d.	Selling price, d.
1329–30	194	(5·5)	...	2·71	7·77	5·82	0·11	16·4	20·0
1332	224	(7·0)	0·65	3·06	7·88	5·38	0·11	16·4	20·0
1333	231	(7·0)	0·60	3·00	7·53	5·43	0·12	16·1	20·0
1333–4	112	7·0	0·60	3·24	8·20	5·57	0·07	17·0	20·0
1350–1	252	7·0	0·96	4·50	15·14	8·19	1·66	29·6	42·0
1352	143	6·8	0·96	4·18	14·92	8·34	3·24	29·6	38·5
1353	39	5·6	1·09	4·57	20·10	9·45	0·83	35·0	38·0
1354	138	5·6	0·92	4·41	18·30	11·00	1·21	34·9	41·0

*Using the estimated weeks of blowing from Table I for the first three entries
†Mining, carriage, and roasting, the latter costing 0·24*d.* per bloom
‡In 1329–34 the other expenses were oil for the bellows and repairs; the high charges in 1350–1 and 1352 were chiefly due to charges for supervision
**A charge of £2 7*s.* 5½*d.* was incurred in 1350–1 for general repairs and one of £1 10*s.* 4½*d.* in 1343; a charge of 0·5*d.* per bloom could be added to allow for such general repairs

together with every seventh bloom; this value has been corrected to a total cost per bloom. In addition they received a bonus per quarter and an allowance for drink which for five out of the eight periods was clearly 1*d.* per week of operation. In the later series of records, when the overall periods of operation and weeks of blowing are given, the ale money is a check on the latter and shows that never more than seven blooms were made per week of blowing, say one per day. If this check is used in the first series of records, when the periods of operation or blowing are not given, an estimate of these periods can be made. Estimated values are bracketed.

The charcoal costs are the most complex and can be given separately to enable the price per load to be carried to a subsequent table.

The effect of the Black Death of 1349 on costs is obvious: it increased mining costs of ore, transport costs of ore and charcoal, and labour costs of blowing by 50%, but the most profound effect was on the cost of charcoal. The dozen of charcoal in Sussex *c.* 1550 cost 3–4*s.*, 25% greater in volume than the decenna of 1330–3, so that the costs for these two periods were thus roughly the same for the same unit; in 1350–4 at Tudeley the charcoal costs had doubled and the price of a bloom had to be doubled to compensate for this. In 1353 some of the charcoal paid a carriage charge of 1*d.*/load, twice that of 1350–2, and half the charcoal supplied in 1354 had the same high carriage cost; charcoal was, in that year, obtained from three sources and it may be this problem of supply which led to the bloomery not being subsequently worked by the lord but leased. The selling price 1350–54 was the very high one of £12 10*s.* 0*d.* per ton, probably exceeding that of imported iron and so encouraging the development of a more efficient process.

The Tudeley bloomery is an example of a relatively primitive one with only one hearth (two bloomeries near Sheffield *c.* 1180 each had two hearths) with inefficient blowing equipment requiring four men and producing only a small bloom. It was, no doubt, an appreciation of these facts which led to the improvement of the equipment for blowing and hammering by using a water-wheel and to the developments at Creskeld, Brancepeth, and Kyrkeknott.

THE BISHOP OF DURHAM'S BLOOMERY AT KYRKEKNOTT, WEARDALE, 1408–9

The records of the Bishop of Durham's bloomery in Weardale represent perhaps as complete a story of the weekly operation of a bloomery as exists in the literature of the world. The membranes have been transcribed by Lapsley[16] in what he describes as its extremely faulty Latin and with interpretations which are as faulty as the Latin. Nevertheless the transcription must be acknowledged to be an extremely valuable contribution, despite the fact that there are a number of errors and omissions. A translation of the description of the building of the forge, the supply of ironstone, and of the accounts for the first 12 weeks of operation, is given in Appendix 1, while a list of the errors and omissions in Lapsley's transcript, based on a microfilm of the ms., is given in Appendix 2.

A summary of the operation of the bloomery is given in Tables III and IV. Any novel statement for the operation after the first 12 weeks is also given in Appendix 1. The total costs were as follows:

	£	*s.*	*d.*			
Receipts						
From William Chauncellor, Constable of Durham	32	0	0			
From the same, per Ralph Eure, the proceeds of the coal mines of Rayley	55	15	11			
			Total		87	15	11
Expenditure						
(1) Preparing the site		15	4			
(2) Mason's work, making the water course	2	10	4			
(3) Carpenter's work making the water wheel, dam and other wooden equipment 6 weeks@3*s.*		18	0			
(4) Felling the trees, 12 weeks@ 2*s.* 6*d.* less 6*d.*	1	9	6			
(5) Making four buildings and the hearths; sawing and carriage of timber	1	5	7			
(6) Tools for the forge and ironstone mines and other metal work	3	17	9			
				£10	16*s.*	6*d.*
(7) 53 dozens of ironstone from						
Sir Ralph Eure royalty@2*s.*	5	6	0			
carriage@2*s.*	5	6	0			
mining@5*s.*	13	5	0			
carriage of cinders		8	0			
				£24	5*s.*	0*d.*
			Total initial costs	£35	1*s.*	6*d.*
(8) Expenditure for 52 weeks of operation (Tables III and IV)	47	18	11			
			Total expenditure	£83	0*s.*	5*d.*
Credit balance				£4	15*s.*	6*d.*

TABLE III Kyrkeknott bloomery, first period

Year	Month	Week ending[1]	Charcoal Amount[2] (d.)	(s.)	Coling,[3] s.	d.	Carriage,[4] s.	d.	Bloom hearth Blooms, no.	Bloomer,[5] s.	d.	String hearth Blooms, no.	Smith,[6] s.	d.	Foreman,[7] s.	d.	Mrs Gylle,[8] s.	d.	Ale, s.	d.	Repairs etc., s.	d.	Total payments, s.	d.
1408	Nov.	17	4	0	8	0	2	0	...	2	0[9]										4	0[10]	16	0
		24	4	0	8	0	2	0	...	4	2[9]												14	2
	Dec.	1*	4	7	9	2	...		6	3	0										4	0[11]	16	2
		8*	4	0	8	0	2	0	3	1	6						7[12]				1	0	13	1
		15	4	6	9	0	2	3	8	4	0										3		15	6
		22*	5	0	10	0	2	6	6	3	0	4	2	4			7				1		18	6
		29*	...		...		...		...	...		...											...	
1409 N.S.	Jan.	5*	...		...		...		...	...		8	4	8	5	0	1	0	1				10	9
		12	3	2	6	4	2	0[14]	6	3	0	6	3	6	2	6	1	0						
		19	5	6	11	0	2	6[14]	6	3	0	6	3	6	2	6	1	0			7		24	1
		26*	3	11	7	10	1	8[14]	6	3	0	4	2	8[15]	1	8		10					17	8
	Feb.	2*	3	4	6	8	1	6[14]	5	2	6	...	...		1	0							11	8
		9	5	3	10	6	2	9[16]	6	3	0	15	8	9	5	3	1	8	1				32	0
		16	4	1	8	2	2	0	6	3	0	...	...		1	3			1				14	6
		23*	4	8	9	4	2	4	5	2	6	9	5	3	2	6	1	2	1				23	2
	March	2*	4	6	9	0	2	3	7	3	6	...	...		(1	3)	...						16	0
		9	4	9	9	6	2	4	7	3	6	...	...		1	3	...		1		3		16	11
		16	3	10	7	8	1	11	8	4	0	...	...		1	3		10½[16]	1				15	9½
		23	3	6	7	0	1	9	5	2	6	11	6	1[15]	2	1	1	2			8[17]		21	3
		30*	3	6	7	0	1	9	6	3	0	6	3	6	2	6		9			4		18	10
	April	6	4	10	9	8	2	4	5	2	6	...	...		(1	3)	...						15	9
	Easter[12]	13*	...		...		0	6[18]	3	1	6	6	3	6	2	6	1	0					9	0
		20	4	9	9	6	2	4½	6	3	0	...	...		(1	0)			2					
		27*	4	0	8	0	2	0	6	3	0	...	...		(1	0)		6[19]	8		10		16	0
	May	4	4	2	8	4	2	2	6	3	0	6	3	6	2	6		8	1				20	3
		11	6	0	12	0	3	0	5	2	6	6	3	6	2	6		8					24	2
		18*	6	0	12	0	3	0	7	3	6	6	3	6	2	9[20]		9	1				25	7
		25	5	8[21]	10	5	2	10	6	3	0	6	3	6	2	6		9	1				23	4
	Pentecost[12]	1*	1	6	3	0		9	3	1	6	...	...			(6)	...		1				5	10
	June	8	7	5	14	10	3	8	8	4	0	9	5	3	3	9	1	3	1				32	10
Totals			120	1[22]	240	2	57	11½	151	81	8	108	63	0	50	3	16	2½	1	9	12	0	523	2

* A Festival or Saint's Day in that period

[1] The Sabbath day (i.e. Saturday) for the preceding week
[2] In dozens (d) and seams (s); 12 seams (pack-horse loads) = 1 dozen
[3] At 2*s.* 0*d.* a dozen
[4] At ½*d.* a seam
[5] John Gylle, paid 6*d.* per bloom
[6] John del Logge paid 7*d.* a bloom hammered and cut into pieces
[7] Thomas Whenfell, paid per bloom, made on the string hearth 2*d* for helping John Gylle and 3*d.* helping John del Logge
[8] Apparently paid 1*d.* per bloom worked in the string hearth for inflating the bellows; for excess see text
[9] Unsuccessful attempts to make blooms
[10] Including 2*s.* 0*d.* to T. Whenfell for making 1 dozen of charcoal, 2*s.* 0*d.* to Will Aycle for travelling to Wakefield and Rotherham for coliers and bloomers
[11] Carriage of 4 dozens of cinders (bloomery slag) to purify the iron; the 4d.–7*s.* charcoal made that week was never carried and accounts for differences in payments for charcoal made and carried
[12] Easter Sunday was 7 April, Whit Sunday 31 May
[13] Breaking and screening ore
[14] Agreement of charcoal made and carried over 5 weeks
[15] 4*d.* excess balanced by 4*d.* deficit w.e. 23 March
[16] Removing ore from 21 blooms
[17] Tallow for bellows
[18] Probably 1d.–0*s.* made by T. Whenfell, 17 Nov.
[19] For her work for this and preceding week
[20] 3*d.* excess
[21] Should be 5d.–4*s.* from payment
[22] Corrected for error (21)

The credit balance given (Appendix 1) was £4 15*s.* 10*d.* The total number of crude blooms (Tables III and IV) was 278 of which 217 were refined and cut into pieces, leaving 61 not so treated (as the final total in the records states), and the 278 blooms weighed 4164 st. (each st. 13 lb). Each bloom was nominally 15 st. of 13 lb (195 lb) and the average actual weight was 0·15% light.

From Table V it may be estimated that to finish the 61 incomplete blooms it would not have required more than 2 seams of charcoal per bloom, or 10 dozen in all. Adding this to the charcoal carried, the average charcoal per finished bloom would be 0·79 doz. or 8·8 seams costing 22*s.* 1*d.* for burning and carriage (no royalty being charged). The Kyrkeknott bloom required 8·8 seams of charcoal (compared with 2·3 seams at Tudeley) for a bloom six times as heavy. The operating cost per finished bloom at Kyrkeknott was 20·25*d.* per bloom compared with 5·6*d.* in 1334 and 12·2*d.* in 1354 at Tudeley when the four men each received a weekly average of 10*d.* in 1334 and 1*s.* 3½*d.* in 1354, compared with 3*s.* for each of the three men of the Kyrkeknott bloomery for the period of Table V (including payments to wives). If the Tudeley workmen had been paid at the daily rate of the Kyrkeknott men the labour cost per bloom in 1332 would have exceeded that at Kyrkeknott despite the fact that the bloom there was six times the weight at Tudeley. Thus the essential feature of the Kyrkeknott bloomery was the production of a bloom six times the size of that at Tudeley with a smaller labour team at less equivalent labour cost, an achievement that surely depended on the full application of the water-wheel, the chief value of which was for operating a power hammer.

The tabular statement shows that the works was completely idle during Christmas week; during the following week no charcoal was made and the bloom hearth was idle, but eight blooms were finished in the string hearth. During Easter week no charcoal was made though 1 dozen in stock was carried; the bloom hearth worked only half the period though the string hearth was active. During Pentecost (Whit week) less than half the usual charcoal was made, the bloom hearth worked for half the period and the string hearth was idle. Lapsley thought that work ceased on Saint's and other Festival days but there is no evidence of this.

Once the bloom hearth was restarted in the second week in January it was idle for only one complete week (27 July) which may be due to the small amount of charcoal carried that week. The operation was remarkably uniform, for in 33 out of the 47 weeks of its operation 6±1 blooms were made; the maximum

TABLE IV Kyrkeknott bloomery, second period

Year	Month	Week ending	Charcoal: Amount† (d.)(s.)	Charcoal: Coling, s. d.	Charcoal: Carriage, s. d.	Bloom hearth: Blooms, no.	Bloom hearth: Bloomer, s. d.	Bloom hearth: Mrs Gylle, s. d.	String hearth: Bloomer, no.	String hearth: Smith, s. d.	String hearth: Foreman, s. d.	String hearth: Mrs Whenfell, s. d.	Ale, s. d.	Repairs etc., s. d.	Total payments, s. d.
1409	June	15*	5 0	10 0	2 6	10	5 0	5	7	4 1	2 11	7	1		25 7
		22	5 9	11 6	2 10	8	4 0	4	8	4 8	3 4	8	1		27 5
		29*	4 0	8 0	1 0[1]	4	2 0	2	6	3 6	2 6	6	1		17 9
	July	6	6 4	12 8	3 2	5	2 6	2½	6	3 6	2 6	6	1		25 1½
		13*	6 4	12 8	3 2	4	2 0	2	9	5 3	3 9	9	1	2	28 0
		20*	5 2	10 4	2 8	4	2 0	2	...	...	(8)	...	1		15 11
		27*	1 6	3 0	9	...	...	...	7	4 1	2 11	7	1		11 5
	Aug.	3*	2 6	5 0	1 6[3]	9	4 6	4½	5	2 11	2 1	2½[3]	1	1 0	17 8
		10*	4 0	8 0	2 0	6	3 0	3	4	2 4	2 1	4	1		18 1
		17*	2 0	4 0	1 0	5	2 6	2½	5	2 11	1 8	5	1		12 9½
		24*	4 3	8 6	2 3	6	3 0	3	5	2 11	2 1	5	1		19 6
		31	5 3	10 6	2 6	6	3 0	3	7	4 1	2 11	7	1	4	24 3
	Sept.	7*	4 9	9 6	2 4	6	3 0	3	...	...	(1 0)	...	1		16 2
		14*	3 8	7 4	1 10	6	3 0	3	12	7 0	5 0	1 0	1		25 6
		21*	2 6	5 0	1 3	4	2 0	2	...	...	(8)	...	1		9 2
		28	4 6	9 0	2 3	8	4 0	4	8	4 8	3 4	8	1	1 10	26 2
	Oct.	5*	4 7	9 2	2 4	6	3 0	3	8	4 8	3 4	8	1		23 6
		12	3 3	6 6	1 7	6	3 0	3	3	1 9	1 3	3	1		14 8
		19*	5 2	10 4	2 8	7	3 6	3½	9	5 3	3 9	9	1		26 7½[4]
		26	5 6	11 0	2 9	6	3 0	3	...	...	...	...	1	1 0	18 1
	Nov.	2*	3 5	6 10	1 9	5	2 6	2½	...	...	...	...	1		11 4½
		9	4 5	8 10	2 2	6	3 0	3	...	...	...	...	1	6 8[5]	21 0
		Totals	93 10	187 8	46 3	127	63 6	5 3½	109	63 7	47 9	8 10½	1 10	11 0	435 9

* A Festival or Saint's Day in that period. All dates in this column refer to the Sabbath Day, i.e. Saturday, for the preceding week
†In dozens (d) and seams (s)
[1] 2d.–0s. made were not carried
[2] Extra ½ dozen carried
[3] Payment at only ½d. per bloom
[4] Given as 26*s.* 6½*d*
[5] Bonus to colier

weekly make was 10 blooms and in another week 9 were made. Thus the usual rate was 1 bloom per day, very occasionally 2 per day. The bloomer, John Gylle, received 6*d*. per bloom and since he made 278 blooms in the 47 weeks (an average of 5·9 per week) he attained an average wage of nearly 3*s*. per week compared with 2*s*. for six days for a labourer.

The string hearth did not operate as regularly as did the bloom hearth, being in operation for 31 weeks and the 217 finished blooms being made at an average rate of 7·0 per week. There were no charges for candles and no increased production in the summer months so that it can be assumed that operations were mostly completed in daylight, which only amounted to 8 h in the winter months. A norm per week of 6 days of 7 blooms finished in the string hearth, which was extended to 9 (4 times), 11, 12, and even 15, implies that 1½ blooms per day was unusual, 2 blooms per day rarely attainable, and 2½ blooms per day was once achieved, possibly extending beyond the week of payment. It is unlikely therefore that finishing a bloom on the string hearth took over 8 h with a normal extension to 12 h on two days per week and exceptionally to 16 h per day for six days, for all weekly productions of 9 or more blooms were preceded or followed by an idle week.

Although half a crude bloom could be treated in the string hearth, it must have been difficult in the bloom hearth to make other than whole blooms and the norm of a bloom per day is what might have been expected. There was however one period in June when 8, 10, and 8 blooms were made in successive weeks and 2 blooms must have been made on 2 of 6 days (twice) and on 4 of 6 days (once) so that a normal period of 8 h for one crude bloom seems likely.

The payments to the chief operators, colier, bloomer, and the smith are clear; those to the auxiliary workers, Thomas Whenfell and to Gylle's wife are not so obvious, particularly to 8 June. After 8 June Whenfell's wife received 1*d*. per bloom made on the string hearth, e.g.:

29 June — And the wife of Thomas Whenfell working at the stryngheath 6*d*. (6 blooms per week)

27 July — [When only the string hearth was operating] 'And the wife of the said Thomas inflating the bellows [*folles sufflanti*] in the said work making VIId' [7 blooms were made].

The association of the work of Whenfell's wife with the string hearth is mentioned on 6 and 13 July and 28 September and with inflating the bellows on 3 August. The agreement between the number of blooms refined in the string hearth and her payment at 1*d*. per bloom

TABLE V Summary of records for five 8-week periods

Period, 1409	Charcoal made, dozens–loads, x	Blooms: Bloom hearth y	Blooms: String hearth, z	$\frac{x^*}{y+z}$	Average blooms per week: Bloom hearth	Average blooms per week: String hearth	Average weekly wages, *s. d.*: Smith	Gylle†	Whenfell†	Cost of ale, *d.*
To 23 February	29–11	40	48	4·5	5·0	6·0	3 6	3 4	2 6	4
To 27 April	23–8	50	17	6·0	6·3	2·1	1 8	3 11	1 5½	12
To 29 June	44–6	54	54	5·0	6·8	6·8	3 11	4 0	2 10	7
To 24 August	32–1	39	51	4·3	4·9	6·5	3 0	2 8	2 7½	8
To 19 October	33–8	49	41	4·1	6·1	5·9	3 5	3 5½	3 2	8
	Totals	232	217							

*Charcoal made divided by sum of blooms made on bloom hearth and string hearth; result expressed in loads
†Husband and wife

shows that her work was inflating the bellows of the string hearth from 8 June to the end of the operation

During the same period Gylle's wife was paid ½*d*. per bloom made on the bloom hearth, e.g.

29 June 'Working at the bloom hearth 2*d*.' [4 blooms made]

6 July 'Working at the bloom hearth 2½*d*.' [5 blooms made]

9 Nov. 'John Gylle; bloomer, making 6 blooms 3*s*. and the cost of the wife of the said John, inflating the bellows [*folles sufflanti*] for making the said 6 blooms 3*d*.'

The payments to Gylle's wife from 8 June to 7 November show that she was paid ½*d*. per bloom made on the bloom hearth, probably for inflating the bellows.

In the period 8 June to 19 October, when the bloom hearth and string hearth were operating, 110 blooms were made at the bloom hearth and 109 refined at the string hearth, a good balance. Since the daily working periods may be estimated to have been the same for both hearths, there must have been a difference in type between the bellows which these women inflated or deflated. Since the string hearth had only to reheat a half-bloom between hammerings, it was probably smaller than the bloom hearth and could (as will be shown later was probable at Rievaulx bloomery in 1542 and at Oxspring bloomery in 1574) probably be operated by foot treadles. This would account for the double charge for operating the string hearth bellows with the bloom hearth bellows operated by the water wheel which could also operate the smith's great hammer.

In the period before 8 June, Whenfell's wife was not employed but weekly payments to Gylle's wife (Table III) agree primarily with the operations of the string hearth, for she was rarely paid when this was not in operation. On the other hand her payments exceeded 1*d*. per bloom refined on the string hearth. Assuming, as seems most likely, that she was paid 1*d*. per bloom refined in the string hearth for operating the bellows there, her total payments to 8 June would give an excess of 76*d*., which agrees with ½*d*. per bloom (151 made) on the bloom hearth. The occasions when her work was described are as follows:

8 Dec. The wife of the said John Gylle, helping him, breaking and screening stone [ore] 7*d*.

22 Dec. inflating the bellows and breaking ore 7*d*. [the first week of operation of the string hearth]

5 Jan. working at the bellows this week

9 Feb. inflating the bellows

29 Feb. auxiliary work at the bellows

16 Mar. removing ore from 21 blooms taking per bloom ½*d*.

23 Mar. for various work

13 Apr. inflating the bellows

Except for 8 December and 6 March the string hearth was in operation on these weeks and the predominating references to the bellows must refer to those of that hearth; for the two weeks when the string hearth was not operating the references are to breaking ore or removing it from blooms. There are two detailed references for the fortnight ending 27 April when the string hearth was not operating and she was paid at the rate of ½*d*. per bloom made on the bloom hearth. If she worked for at least 8 h per day on the treadles of the bellows (deflating) of the string hearth she could, with suitable cords and pulleys, inflate the bellows of the bloom hearth instead of operating a distaff as in Fig.1. As previously noted, all the occasions when over six blooms were made on the string hearth were preceded by an idle week on the string hearth in which she could have performed her supplementary duties on the bloom hearth, so that if she did not deflate the bellows of the string hearth and the inflating cord of the bloom hearth bellows at the same time, her work on the string hearth could have been for 8 h with her auxiliary work on the bloom hearth (if not inflating the bellows) carried out outside that period. After 8 June, when the bellows of both hearths were inflated or deflated by two women, over six blooms were made in three weeks without an idle week before or after, an improvement on the preceding period. We cannot be certain that Gylle's wife regularly inflated the bellows of the bloom hearth before 15 June and can only conclude that she could have done either this or prepared ore for the bloom hearth.

The payments to Thomas Whenfell began with the operation of the string hearth, apart from the payment to him on 17 November for making 1 dozen of charcoal. He may have been employed as a charcoal burner until the string hearth was started, for the average payment per week over five periods of eight weeks was 8*s*. for 4 dozen of charcoal, which could have been for four men (6 days at 4*d*./day, a labourer's rate). John Mody was paid for making the charcoal but is not mentioned after 29 June, while John Laybourne was given a bonus at the end of the campaign for working during the whole of the time. In Tables II and III the payments to Whenfell agree with the blooms refined in the string hearth except where bracketed for periods when the string hearth was idle. Whenfell's first payment on the string hearth covers also the week ending 22 December when the string hearth was started and his 5*d*. per bloom refined was described as 2*d*. per bloom for the first stage (working with John Gylle) and 3*d*. for the second stage (working with John del Logge). His seven weekly payments when the string hearth was not working were at the rate of 2*d*. per bloom made on the bloom hearth for five weeks, 2*d*. per bloom with 1*d*. bonus on 2 March, and 3*d*. per bloom on 6 April.

Whenfell seems therefore to have helped the smith and the bloomer but his payment was based primarily on refined blooms on the string hearth. Since this normally handled more blooms than the bloom hearth, this basis should have been to his advantage, but in the second period of eight weeks in 1409 the string hearth was idle for so many weeks that Whenfell's average rate of payment fell below that of a labourer. For general comparison the operation during 1409 until the string hearth stopped can be divided into five periods each of eight weeks, omitting Easter week and Pentecost when operations were much restricted by holidays. The records are summarized in Table V.

The replacement of Gylle's wife by Whenfell's wife on the bellows of the string hearth from 8 June still left the Gylle family with the highest average wage over the whole period and the Whenfells received the lowest average wage during the second period (less than that of a labourer). This was probably due primarily to the fact that the smith, John del Logge, was not available during most of the second period. Ale was not supplied regularly each week until after

TABLE VI Lists of tools of bloomeries

Bloomery	Tudeley, 1350			Kyrkeknott, 1408	Rievaulx, 1542	Oxspring, 1574	
Value of 1 ton of blooms	£12 10*s.* 0*d.*			£4	£2 12*s.* 0*d.*	£10	
	No.	*s.*	*d.*			Bloomer	Smith
Pairs of tongs*	2	2	6	2	2 (bloom) 2 (string)	2	
Tuyeres	2	2	8	3	4	2	2
Axes	1	1	3	3	4	4	2
Hand hammer	1		1	} 3	1	} 3	} 2
Little hammer					1		
Great hammer					1		
Anvils				3	1		1
Andirons	1		8	5	1	4	4
Looms	1		2¼		2	1	1
Treadle pins				2†	5	2	
Hooks					6	3	2

* *Zounes* (zones), incorrectly transcribed as loves (Tudeley), lores (Rievaulx), and lomes (Oxspring)
† Sword blades, probably on the string hearth

11 May but eight week's normal supply during the week ending 27 April make the total for the second period, in Table V, unusual and suggest than at allowance of 1*d.* per week was regarded as customary, as in fact it was at Tudeley *c.*1350; it probably represented 4 gallons.

It will be observed that the charcoal consumption was the least economical when the string hearth was little worked in the second period and tended to fall with the better organization for the last two periods (Table V).

Thus Thomas Whenfell, from the records given in Table V, received less pay through his wages being based primarily on the blooms refined in the string hearth but this was entirely due to the number of idle weeks for the hearth in the second period of Table V and the substitution of his wife for Gylle's wife for the bellows of the string hearth was probably some compensation; it gave them in the third to fifth period of Table V an average wage above that of the carpenter on casual work (2*s.* 6*d.*/week).

The evidence in favour of the use of the water-wheel to operate a hammer is indirect. In later practice a separate water-wheel was usual for the hammer so that the speed of this could be regulated if necessary. It would have been practicable to operate one set of bellows and a hammer from the water-wheel, the bellows for the bloomery hearth being comparatively small, but the use of one wheel would have meant that the speed of the hammer could not be regulated; it could have been thrown out of action but when in action would have operated at a uniform rate. For the simple operations of a bloomery this would have been no disadvantage.

The evidence in favour of the use of water-wheel operated hammer at Kyrkeknott can be deduced from lists of the tools at Tudeley, Kyrkeknott, Rievaulx, and Oxspring bloomeries. These are recorded in Table VI together with costs of the tools at Tudeley.

The argument depends on the fact that the essential tools of a smith were a hammer and its counterpart, an anvil, with tongs to hold the hot iron. The word anvil (anvell, anfeld, anfilt) can be traced back in English usage to 800 A.D. with a Latin equivalent of *incus*, *incudis* (from *cudo-ere*, to beat or thresh) but the Latin of the Kyrkeknott scribe was faulty and he often had difficulty in finding the correct Latin for a vernacular term of the workmen. That this was not uncommon is shown by the incorrect labelling of tongs as *incudis* in a drawing in a late 13th century manuscript reproduced by Schubert[17] without comment. The Kyrkeknott bloomery, newly erected, required anvils and the name applied by the scribe was 'iii *tribul*', which Lapsley expanded to *tribulis*, the plural of *tribulum*, a threshing sledge. On the other hand, lack of mention in the Tudeley inventory of 1350 (when it was rebuilt) is of no significance, since anvils would be available from earlier years; there was one in the stock at Tonbridge Castle in 1325, believed by Giuseppi[18] to have been associated with Tudeley.

Schubert[19] transcribed the records of the Rievaulx bloomery, and his transcription has been confirmed in essentials by an independent archivist, Dr L. A. Parker of the County Record Office, Leicester. The record may, however, be a copy with the copyist making three mistakes in transcription which led Schubert to make interpretations which cannot be correct. For the present purpose Schubert's most obviously incorrect interpretation is for the line:

Item for iij tuernes & a cantell ixs iiij*d*

It will be shown later that the three tuyeres probably cost 2*s.* 6*d.*, leaving 6*s.* 10*d.* for a 'cantell' which Schubert interprets via Fr. *chanteau* a piece of cloth, a mask, but this would cost only 1*d.* and a cantell must be the most expensive item in the bloomery. It is probable that the copyist misread the original 'an anvell' which would cost an appropriate amount.

In the records the words 'a payer of blome lores' and 'a peare of stryng lores' occur. Schubert interprets 'lores' as thongs or the leather sides of the bellows but thongs in Latin are *lorea* and the account is in English, and the leather sides of bellows cannot be described as thongs, which are narrow pieces of leather. The most likely original word is 'zones', i.e. tongs which Giuseppi[18] incorrectly transcribed as 'loves'.

The third probable error of the original copyist is 'ij lowes' (which Schubert interprets as 'loves' after Giuseppi) but 'lomes', vessels for water to restrain the fire, is more likely. The Rievaulx record is as follows:

pd for iiij^{or} axis/ a Tuerne/ a payer of blome lores a peare of stryng lores/ ij lomes/ a sheller & a hamer		vij*s*
Item for iij tuernes & a cantell	ix*s*	iiij*d*
Item for fyve tredlepynnes syx iron haukes ij lowes abrod iron shovyll/ a forgayn/ a Sheller/ a great hamer/a lyttyll hamer		V*s* V*jd*
* Item for a petell of [?O] yle for the Bellowys		xiij*d**
Item for a whelebarowe		vj*d*
* Item pd to Rawlynsen for makyng of iiij^{or} axis &		
for a pecke of See Coles		V*d*†
for a buytt to cary water to blome harth		ij*d*
Summa xxiiij*s** xxij*s*		vj*d*

*These entries are crossed out in ms.; the entry xiiij*s*, iiij*d*, has now been confirmed on the original
†This presumably should be crossed out.

The application of Tudeley prices to the first item, counting a sheller as an andiron, gives a total of 9*s*. 11½*d*. The discrepancy probably arises because the Tudeley price of iron, £12 10*s*. 0*d*. per ton, was abnormally high due to the Black Death; by reducing the Tudeley prices to two-thirds, approximate agreement with the actual total is obtained and such values are used subsequently. This leaves a value of 6*s*. 5*d*. for the anvil in the second item which, allowing half the cost for workmanship and the current price of Rievaulx blooms 3*s*./cwt, gives an anvil of at least 1 cwt.

The same method may be applied to item 3. Counting a furgon as an andiron and allowing 4*d*. for the shovel and 1*d*. each for a pin and a hook leaves 3*s*. for the great and little hammer, half of which for the iron would give a weight of 100 lb for the two hammer heads. This is low compared with the 5-cwt hammer heads of the great hammers of the Sussex forges but the water-wheel operated hammer head illustrated by Agricola (and reproduced by Schubert, Fig.20) for 1550 would only be of about ½ cwt.

The same method may be applied to obtain an estimate of the weight of the 'iii tribul' at Kyrkeknott, taken to mean anvils. Unfortunately, the skin which describes the making of iron tools (following the making of the bloom hearth and before the delivery of the ironstone, Appendix 1) is damaged in two places which give the total of two items, one of which is a pair of bellows for which only 4*s*. 4*d*. is readable. It is assumed that this should read 14*s*. 4*d*.* (a pair of bellows at Tudeley cost 12*s*. 0*d*.), which leaves 24*s*. 7*d*. for 3 pairs of tongs, 2 axes, 1 rake, 1 chilour (counted as 2 andirons), and 3 'tribul'. By the method previously used all items but the tribul total 4*s*. 2*d*., leaving 20*s*. 5*d*. for '3 tribul', which exceeds three times the price assigned to the Rievaulx anvil.

The same method can be applied towards the end of the same paragraph where '3 tuyeres, 3 andirons, 1 axe, a balance, and 3 hammers' cost 7*s*. 8*d*. for fabricating and 22 stones (286 lb) iron were allocated to replace that to be transferred later, the fabricating cost being 4½*d*. per Imperial st. The cost of labour and materials of Kyrkeknott iron was £3 per Imperial ton or 4½*d*. per Imperial st., this being the basis of the half charge for metal used above. The balance may be assumed to be the steel yard which was widely used for commercial transactions and was not prohibited for such until 1429.[20] Using one third of the Tudeley costs leaves a sum of 4*s*. 9*d*. for the hammer which at 4½*d*. a st. gives a weight of 1½ cwt and allows at least one power hammer of 1 cwt. The same entries may be analysed by estimating the weight of the items other than the hammers, allowing 1 st. for each; this leaves 14 st. (13 Imperial st.) for the three hammers, approximately the same estimate as by the other method.

Supporting evidence for the use of a water-wheel operated hammer is given by the cost of 2 gudgeons and 2 hoops for the axeltree of the water-wheel (21*s*.), which at 4½*d*. per (Imperial) st. for making and the same amount for the iron itself gives a weight of 3½ cwt. Gudgeons or pins were fitted at the end of the water-wheel shaft, working in bearings, and the hoops were usually on the hammer shaft, e.g. the inventory, at Lydbrook Forge, 1635[21]: 'The great Hammer beams with the wheel, with 13 yron hoops, 2 great gudgeons and brasses of about 3 c of cast iron and 2 yron hoops about the anvill blocke'. Such massive mounting of the axeltree would not have been required merely to depress the bellows, which could be manually or foot operated.

Thus the Kyrkeknott accounts allow for more costly hammers and anvils than at Rievaulx where Schubert accepts the 'great hammer' as indicating water-wheel operation. Schubert interprets the treadle pins of Oxspring bloomery as implying the pins for a treadle for a hammer—an oliver—but ignores those of Rievaulx. It is quite possible, bearing in mind the ease with which (with well designed treadle boards) a pair of bellows for an Osmund furnace could be operated (Fig.1), that the bellows at Rievaulx and Oxspring were treadle operated; this seems a more reasonable assumption than that the primary use of a treadle was to operate a hammer.

It is concluded that, at the Kyrkeknott bloomery of 1408–9 operated by a water-wheel, the practice, then common in France, of using the water-wheel for the hammer was applied and that the water-wheel was also used to operate the bellows of the bloom hearth but not those of the string hearth. The ability, using a water-wheel operated hammer, to handle a bloom of 2 cwt gave the necessary impetus for development of the iron industry in the 15th century, before the introduction of the charcoal blast-furnace.

* See footnote p.159

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APPENDIX The Bishop of Durham's bloomery in Weardale, 1408–9

1. Translation of G. T. Lapsley's transcription[1] of the original[2]

Kyrkeknott, overseeing of the said iron minerals

BISHOP LANGLEY

Account of John Dalton overseer of the new iron forge at Kyrkeknott[3] near Bedbourne [Bedburn] from 12 June, 9 Henry IV the second year of the consecration of Lord Thomas, Bishop of Durham to the feast of St. Martin in the year following, one whole year and 102 days.[4]

RECEIPTS

Item he answers for £32 received from William Chauncellor, Constable of Durham by indenture. And of . . .[5] 15*s.* 11*d.* received from the said Constable by the hand of Sir Ralph Eure, the proceeds of his mineral coal of Rayley[6] by indenture. *Sum total received* £87 15*s.* 11*d.*

Preparing the site of the forge Of which he computes the cost of John Gylle 'smythman', in preparing the site for a new forge for the smelting of the ironstone, by agreement with him, 13*s.* 8*d.*[7] And his costs and expenses for horses in going with Thomas Child to Blakamore[8] to see a similar forge the better to build the new one, for 3½ days at 6*d.*, 1*s.* 8*d.* *Sum* 15*s.* 4*d.*

Making the water course [*Watergate*] And paid to Roger Colly, mason, Robert Hopynland, John Symmesone [Simpson] John Killingham and John Dyksone [Dickson], labourers, for making a water course extending from Hartborne[9] to the said

[1] G. T. LAPSLEY: *Eng. Hist. Rev.*, 1899, *14*, 509.

[2] Public Record Office (PRO), Durham Auditors' Vouchers (Durham 20/114).

[3] Lapsley gave 'Byrkeknott' which has been corrected to 'Kyrkeknott': the 'church-hill' is probably that of Hamsterley, where the church is early 13th century.

[4] From 12 June 1408 to 11 November 1409; 102 days is, of course, a mistake—it should have been 153 (Lapsley).

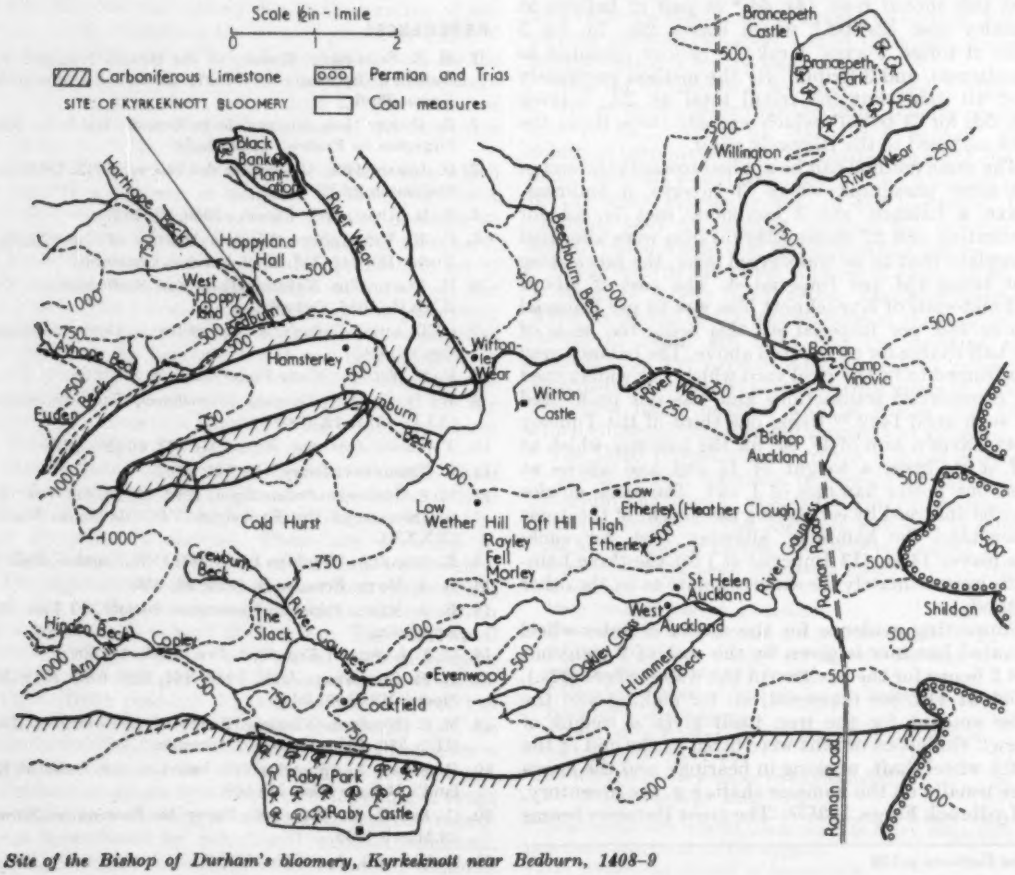
[5] The missing figure in the damaged skin must be £55 to give the sum total received.

[6] The ore was found in the Coal Measures: *see* Fig.2.

[7] At 6*d.* per day, 3*s.* per week, this would represent 4 weeks work, i.e. 8 June to 10 July.

[8] This is probably Black Moor (now a golf course) near Moortown, Leeds, a journey of 70 miles which would take 1 to 1½ days.

[9] Lapsley gave this as 'Heribourne'. This is now read as 'Hartborne', i.e. Hartburn or stream, probably identical with the present Harthope Beck (*see* Fig.2), 'hope' being a blind valley; this is confirmed by the siting of the bloomery at Harthope Mill by excavations carried out by R. F. TYLECOTE: *JISI*, 1960, *194*, 451–458.



2 *Site of the Bishop of Durham's bloomery, Kyrkeknott near Bedburn, 1408–9*

forge, and making a stone gutter because of the poor foundations, for 30 days at 4*d*. as well as 4*d*. for the wife of Robert Hoppynland helping in the work. *Sum* 50*s*. 4*d*.

Making the forge house, water wheel, the spouts, bellows and other necessaries for the forge And the hiring of Thomas Gylle, carpenter, for six weeks before the Feast of the Assumption of the Blessed Mary[10] at 3*s*. 0*d*. a week in making, for the said forge, a new water-wheel [*rota aquatica*] dam and wooden spouts to lead the water from the water course to the wheel, as well as the bellows and other wooden instruments required for the new forge, by agreement with him, 18*s*. 0*d*. and hiring of William Prestone and John Crowe for felling trees for this work, and helping the said Thomas for the above period, at 2*s*. 6*d*. per week, deducting 6*d*. for one day when the said John was absent 29*s*. 6*d*.

And the hiring of Roger Coley, carpenter, for making and building four new buildings for 4 days at 5*d*., 1*s*. 8*d*.[11] And the hiring of John Dykson helping with this work at 4*d*., 1*s*. 4*d*. and the sawing of timber for the dams and other necessary features stated above, by agreement with two sawyers 4*s*. 1*d*., and the hiring of John Colersowe with his wain for the carriage of 14 loads of timber from the park of Bedbone[12] and the Blakbank[12] at 8*d*. a load and one at 10*d*. carrying an axeltree for the water-wheel from the park of Blakbank, 10*s*. 2*d*., and the hiring of John Gylle making the bloom hearths and the forge by agreement with him 3*s*. 4*d*.,[13] and the hiring of the same person for covering the said forge with turf 5*s*. 0*d*.[14] *Sum* 73*s*. 1*d*.

Purchase and making of tools And for 2 pairs tongs,[15] 2 axes, 3 anvils,[16] 1 rake, 1 chilour[17] as well as other tools of iron . . .[18] and for 2 pairs bellows[19] bought from . . . near Ripon by John Falderley, sen. . . . 4*s*. 4*d*.* And for 2 measures for ironstone each containing 2 bushels, 3*s*. 6*d*. And paid to John Smythe of [West] Auckland for making various iron rods and sharpening them for winning the ironstone from the quarry from iron supplied by himself,[20] his time compute 2*s*. 3*d*. And paid to Robert Hedley for 2 bands and 2 gudgeons of iron weighing— lb for the ends of the axletree of the water wheel £1 1*s*. 0*d*.[21] And the same for 100 spikes [10*d*.] 360 short nails at 8*d*. a 100, (2*s*. 3*d*.), 100 small keys (4*d*.), 3*s*. 5*d*. And the hiring of John Smyth of West Auckland for making, from 22 stones of iron to be returned from the products of the new forge, 3 tuyeres[22] 3 pokers[23] 1 scale to weigh the iron, 3 hammers,[24] 1 axe and also other diverse tools of iron by agreement with him, 7*s*. 8*d*. And a sieve to clean the ironstone cost 1*s*. 0*d*. *Sum* 77*s*. 9*d*.

Wages, cost and carriage of the ironstone And for 53 dozens of ironstone from Sir Ralph Eure for ironmaking, a dozen at 2*s*. 0*d*. by agreement with him £5 6*s*. 0*d*. and the carriage of the said 53 dozens from the said pits to the said forge, a dozen at 2*s*. 0*d*., £5 6*s*. 0*d*. and the price of Ralph Sclater [Slater] with his wain for 12 days at 8*d*. for the carriage of cinders from the said field compo de Hopyland[25] to the said forge to temper the new iron by agreement, 8*s*. And the wages for the said 53 dozen of ironstone, a dozen containing 3 fothers[26] namely, 20 dozen 1 fother from Rayley,[25] 18 dozens from Hertkeld, 14 dozens 2 fothers from Morepytt, a dozen at 5*s*. by agreement with the said labourers £13 5*s*. 0*d*. *Sum* £24 5*s*. 0*d*.

The Sabbath day 17 November, 10 Henry IV for the week preceeding. And wages paid to John Mody colier for cutting down the undergrowth in the Lords park at Bedborne and from it burning 4 dozens coles called charcole to smelt the said ironstone at 2*s*. a dozen, by agreement with him, 8*s*. And the wages of Thomas Whenfell for burning 1 dozen, 2*s*. And the carriage of the said 4 dozens coles from the said forge, a dozen at 6*d*., 2*s*. And the wages of John Gylle, smythman or blomer, for unsuccessful attempts to make iron this week, 2*s*. And William Aycle for his costs and expenses by horse back to Wakefield and Rotherham for workmen called blomers and coliers for the said forge, 2*s*.[27]

The Sabbath day 24 Nov. for the week preceding. And paid to John Mody in the said park cutting down the undergrowth and from it burning 4 dozens of coles at 2*s*. a dozen, 8*s*. And paid for the carriage of the said 4 dozens to the said forge, 2*s*. And the wages of John Gylle, smithman or blomer for unsuccesful attempts to make iron, this week by bond, 4*s*. 2*d*.

The Sabbath day 1 December in which occurred the Feast of St. Andrew the Apostle. And paid to John Mody and helpers for cutting down wood in the said park and burning it 4½ dozens 1 seme a dozen as above, 9*s*. 2*d*.[28] And the carriage

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[10] This fell on 17 August in 1408; say 10 July–17 August (*see* note 7).

[11] Although Roger Colley has been previously described as a mason these four buildings were probably of wood and used for housing the bloom hearth, the string hearth, the charcoal store, and the forge workers.

[12] The hamlet of Bedburn and Black Bank Plantation are found in modern O.S. maps: *see* Fig.2.

[13] At 5*d*. per day this would have taken eight days, compared with four days to make the buildings with two men. The fact that John Gylle built the hearths suggests that it was he who went to Blakamore.

[14] At 5*d*. per day this is 12 day's work, more than for the building of the hearth of the buildings.

[15] Lapsley gives this as 'Lysours' and suggests mending it to 'sysors'; the Latin *zounes* was usually used for tongs which were mentioned later in the campaign.

[16] The original (often contracted) gives (iii) *tribul ferri* which Lapsley expanded to *tribulis*. *Tribulo*=to thresh, *tribulum* =threshing sledge. Since the hammers are listed separately this is probably the scribe's word for 'anvil'.

[17] *Cath. Angl.* gives "choller' a kind of rake, a coul rake'.

[18] This amount should be 34*s*. 7*d*. to give the stated sum.

[19] Thomas Gylle had already been paid for 'les belowes'. Perhaps these were the special bellows for the string hearth, and coming from Ripon near to Black Moor, Leeds, would be of the type seen at Black Moor.

[20] Later 16 st. 8 lb of iron were returned to Sir Ralph Eure for the iron used: *see* penultimate paragraph. This suggests that John Smyth was the Bishop's blacksmith. The payment is only 1·65*d*. per st. compared with 4*d*. per st. (note 24).

* This has later been read as 14*s*. 4*d*.

[21] This high cost for what were in effect the bearings of the water-wheel is an indication of the massiveness required with a power hammer.

[22] Blast pipes.

[23] *iii porres alias naundirens;* literally 'hand irons'.

[24] The fabricating cost was approximately 4*d*. per stone compared with 1*s*. 6*d*. per st. of the materials of note 20; allowing 1 st. for each of the other named articles this leaves 14 st. of iron for the three hammers, or 183 lb. Some of these hammers must have been hand-operated. The head of a tilt hammer for steel in Sheffield practice was 150–200 lb (URE: 'Steel', *Dict. of Arts*, 1839), so that at least one of the three hammers is likely to have been a heavy one operated by the water-wheel.

[25] Hoppyland and Rayley are found in modern O.S. maps (*see* Fig.2); a hoppy is a pony.

[26] Since 25 tons of iron were produced from this stone containing 33% iron, and half the iron must have gone into the slag, 150 tons of ironstone must have been required; a dozen would weigh about 3 tons which equals 3 fothers, a fother being a wainload usually of 1 ton. The dozen of charcoal contained 12 seams or pack-horse loads, as it did in south Yorkshire in 1750. In south Yorkshire the dozen of ironstone was 60 seams or pack-horse loads, each of about 2¼ cwt. This shows that the Kyrkeknott ironstone was conveyed by wain which cost 8*d*. per day per load, or 2*s*. a dozen as stated above, or 159 days for the total; the forge took 153 days to prepare so that the carriage must have been completed about the time the bloomery started.

[27] Since William Mody had 'helpers' the next week but one, Aycle only succeeded in obtaining coliers.

[28] This and other entries, e.g. 12 Jan., show that 12 seams equals 1 dozen.

of 4 dozens cinders from . . . to the said forge to temper the newly-made iron, 4*s*. And John Gylle, blomer, for making blomes this week, at 6*d*. a blome, 3*s*. *Sum* 16*s*. 2*d*.

The Sabbath day 8 Dec. . . . Feast of St. Nicholas and the Conception of the Blessed Mary. And the said John Mody and helpers burning 4 dozens coles, 8*s*. And the carriage, 2*s*. And John Gylle making 3 blomes this week, 1*s*. 6*d*. And no more this week since the bellows were broken. And the wages of the wife of the said John Gylle, helping him, breaking and screening stone,[29] 7*d*. And the purchase of oil[30] to annoint the bellows, 8*d*. And for the making of a new path into the park for the better carriage of the coles, 4*d*. *Sum* 13*s*. 1*d*.

The Sabbath 15 Dec. And paid to John Mody for burning 4½ dozens coles in the said park, 9*s*.

And their carriage to the said forge, 2*s*.[31] And paid to John Gylle, blomer, for making 8 blomes this week, the blome as above, 4*s*. And cord bought for the bellows to replace broken cords 3*d*.[32] *Sum* 15*s*. 6*d*.

The Sabbath 22 Dec. [in which fell] the Feast of the St. Thomas the Apostle. And paid to John Mody . . . 5 doz. coles . . . 10*s*. And their carriage . . . 2*s*. 6*d*. And . . . John Gylle making 6 blomes this week, 3*s*. And John de Logge,[33] smith, making and cutting into pieces[34] 4 blomes this week, taking for each blome 7*d*., 2*s*. 4*d*. And the wife of John Gylle for inflating[35] the bellows and breaking ironstone, 7*d*. And carrying a tuyere from the forge to West Aukland for repairs, 1*d*. *Sum* 18*s*. 6*d*.

The Sabbath day 5 January [in which fell] the Feast of the Circumcision of our Lord. And John del Logge making and cutting into pieces 8 blomes of iron, 4*s*. 8*d*. And the wages of Thomas Whenfell, forman, working both with John Gylle, bloomsmyth, in the first stage [*in prima factura*] and with John Logge, smith in making and purifying the iron [*in fabricatione et purificatione ferri*], this week, taking for each bloom for the first stage 2*d*., and making and purifying 3*d*., and therefore for each blome a total of 5*d*. and for 12 blomes this week, 5*s*. 0*d*., and the wife of the said John Gylle at the belowes this week, 1*s*. 0*d*. and for ale for the said workmen this week, 1*d*. *Sum* 10*s*. 9*d*.

The Sabbath day 12 January. And paid to John Mody for 3 dozens 2 seams coles, a dozen at 2*s*. 0*d*. as above, 6*s*. 4*d*. And their carriage from the said park to the said forge, 2*s*. 0*d*., and John Gylle, blome smyth, making 6 blomes, as above, 3*s*. 0*d*. And John Loge, smith, the said 6 blomes,[36] making and cutting into pieces 3*s*. 6*d*. And Thomas Whenfell, forman for his labour on the said 6 blomes,[36] making and purifying, 2*s*. 6*d*., and the wife of the said John Gylle working at the bellows [*ad les folles laboranti*] for this week, 1*s*. 0*d*. *Sum* 18*s*. 4*d*.

The Sabbath day 19 January and paid to John Mody for 5½ dozens coles, as above, 11*s*. 0*d*. And paid for carriage of 6 dozens and 6 semes[37] from the said park to the said forge, 2*s*. 6*d*.[37] and paid to John Gylle, blomer, making 6 blomes this week, 3*s*. 0*d*. And John Loge, smith, making and cutting into pieces 6 blomes, 3*s*. 6*d*. And Thomas Wynfell, forman, for the same work this week, 2*s*. 6*d*. And paid for 1 trough [*trowe*] for the strynghertb 4*d*. And paid the wife of John Gylle the same work this week, 1*s*. 0*d*. And paid John Felanceby for 2 sword blades [*swerdblad*][38] for the belowes, 2*d*. And for the repair of the iron tongs [*tanges*] to the same, 1*d*. *Sum* 24*s*. 1*d*.

The week ending the Sabbath 26 January on which fell the Conversion of Saint Paul. And paid to John Mody for 3½ dozens and 5 semes[37] coles, 7*s*. 10*d*. And their carriage . . . 1*s*. 8*d*.[37] And John Gylle, blomer, making 6 blomes, as above, 3*s*. 0*d*. And John Loge, smith, making and cutting into pieces 4 blomes 2*s*. 8*d*. And Thomas Whynfell, forman, working over and making the said blomes 1*s*. 8*d*. And the wife of the said John Gylle for auxiliary work, 10*d*. *Sum* 17*s*. 8*d*.

The week ending the Sabbath the 2nd February in which fell the Purification of the Blessed Mary. And John Mody for burning 3 dozens 4 semes coles 6*s*. 8*d*.[37] And for their carriage . . . 1*s*. 6*d*.[37] And John Gylle, blomer, making 5 blomes this week, 2*s*. 6*d*. And Thomas Whynfell, forman, the same work this week, 1*s*. 0*d*. *Sum* 11*s*. 8*d*.

The Sabbath the 9th February. And the said John Mody for burning 5 dozens and 3 semes of coles in the said park 10*s*. 6*d*., and their carriage . . . 2*s*. 9*d*.[37] And John Gylle, blomer, making 6 blomes, 3*s*. 0*d*. And John Loge, smith, making, cutting into pieces 15 blomes this week, 8*s*. 9*d*. And Thomas Whenfell, forman, helping the said John Gylle and John Loge, this week 5*s*. 3*d*. And the wife of the said John Gylle inflating the bellows [*folles sufflanti*] 1*s*. 8*d*. And for ale for the said workmen, 1*d*. *Sum* 32*s*. 0*d*.

[*The subsequent details are so repetitive that the salient details for succeeding periods (and for those already given) have been summarized in Tables III and IV. Other details not included in the tabulation are as follows.*]

9 March	And the cost of making 1 hake and 1 hammer for breaking ironstone 3*d*.
23 March	And William Cowton, smith, repairing various iron goods, 4*d*.
13 July	And for cleaning and repairing a defective dam, 2*d*.
3 Aug.	And the cost of a smith in repairing and sharpening various iron tools as well as putting in place an iron gudgeon at the end of the axletree of the water-wheels, 1*s*. 0*d*.
31 Aug.	And the repairing of tools and the forge goit [fleme], 4*d*.
28 Sept.	And paid for making 2 pairs new bannasters[39] to carry stone, 1*s*. 0*d*.
26 Oct.	And 1 pair new banastres[39] to carry stone, 1*s*. 0*d*.
9 Nov.	And John Laybourne, colier[40] by the hand of John Falderle, jun., a bonus for his good and diligent work in burning coles for the whole of the above period, 6*s*. 8*d*.

After the entry for 9 November 1409 the record ends as follows:

Sum total £83 0*s*. 1*d*. And remains £4 15*s*. 10*d*. which is carried forward to the following compotus. And it is balanced.

On the back of the roll

Compotus John Dalton Custodian and Appropriator of the Lord Thomas, Bishop of Durham, for the iron mines near Kyrkeknott 10 Henry IV.

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[29] Ironstone.

[30] Probably tallow, which was a regular feature in later practice.

[31] Should be 2*s*. 3*d*. for the quantity and the total, the mistake being the scribe's.

[32] A balance weight was later used to *inflate* the bellows after deflation by the tappets of a water-wheel; the use of a cord was probably an early method of doing this.

[33] John del Logge had a bloomery in Weardale in 1375. Apparently Aycle was not successful in persuading bloomers to come to Weardale and the services of John del Logge were secured; he stayed until the campaign ended a year later.

[34] Iron was sold as blooms, slabs, and bars, but chiefly as pieces (peces), possibly 24 pieces per bloom (*c*. 8 lb per piece).

[35] *Sufflo*, to blow upon or inflate. Since this charge first appeared when the string hearth was being operated by John del Logge, it must be for this hearth (perhaps operated by treadle), the bloomery bellows being worked by the water-wheel.

[36] The working in the two hearths was now combined to avoid reheating.

[37] Disagreement between the amounts coled and carried 12 January to 9 February compensate at the end of this period.

[38] Probably used as hangers (instead of the cord which broke on 15 December) to connect the bellows to the foot treadles on the string hearth.

[39] Panniers for pack horses.

[40] John Mody, who was in charge of wood-cutting and coling at the start, was not mentioned by name after 22 June.

The above computation returns 278 blomes of iron from the products of the said iron mines, made in the said forge; and made in the time computed, as shown, of which each blome contains 15 stones and each stone contains 13 lb.

Sum 278 blomes containing 4164[41] stones and 61 blomes not yet worked up into iron.

Of which it is computed was released to John Smythe of West Auckland for making various iron tools for the iron mines, accounting for 22 stone iron. And released to Sir Ralph Eure to replace so many stones of iron borrowed for making the iron tools for the iron quarries as well as for the tools on the forge 16 stones 8 lb iron. And released for the Lord to Thomas Rose, supervisor of the said works 12 loads[42] containing 2040 stones.

Sum 2078 stones 8 lb and remains 2885[43] stones 5 lb, and 61 blomes not yet worked up into iron and all carried forward in the following compotus.

2. Errors and omissions in Lapsley's transcription

Page

516 Byrkeknott should be Kyrkeknott.
Heribourne should be Hartborne (also p.517, 3rd paragraph).

517 End of 1st paragraph: total should be £87 15*s.* 11*d.*, not £88 15*s.* 11*d.*

518 End of 1st paragraph: the sum should be 73*s.* 1*d.*
There should be only one total (3*s.* 5*d.*) for the three sorts of nails with the details of each sort as subscripts (10*d.*, 2*s.* 4*d.* (2*s.* 3*d.* being an error), and 3*d.*).
Lapsley's note 44 to explain towirens (tuyeres) is incorrect.
The total sum for the last paragraph and marginal note should be £24 5*s.* 9*d.*, not £13 5*s.* 0*d.*

519 2nd paragraph: the total paid to John Gylle was 4*s.* 2*d.*, not 3*s.* 2*d.*

520 12 January: the amount of charcoal made was 3 dozen 2 seams, not 4d. 2*s.*

521 19 January: before item to John Felanceby *Et soluta uxori Johanni Gylle ibidem laboranti iste septima xiid* has been omitted.
26 January: the sum should be 17*s.* 8*d.* (also in margin).
16 February: the charge for making charcoal should be 8*s.* 2*d.*, not 9*s.* 4*d.*

523 27 April: the last sum for repairs is 3*d.*, not 4*d.*

524 18 May: *Et John Loge fabro fabricanti et in pecias dolanti VI blomes iiis vid* has been omitted.
25 May: the quantity of charcoal made was 5 dozen 8 seams, not 5d. 6*s.*
8 June: *Et Thomas Whenfell forman ibidem laborenti iiis. ixd* has been omitted.

525 6 July: *Et John Loge fabricanti et in pecias dolanti vi blomes iiis* has been omitted.
13 July: the carriage charge for charcoal was 3*s.* 2*d.*, not 4*s.* 2*d.*

526 10 August: *Cariagio iis* has been omitted.
31 August: John Gylle made 7 blooms, not 6.

527 5 October: the amount of charcoal was 4 dozen 7 seams, not 3d. 7*s.*, and the cost 9*s.* 2*s.*, not 7*s.* 2*d.*

528 12 October: *Et uxori suae eidem adjuvanti in opere praedicto iiid* has been omitted.

[41] Would be 4170 if the nominal weight of 15 stones per bloom had always been attained.
[42] 1 load equals 2210 lb or roughly 1 ton.
[43] Should be 2085 st. 5 lb.

An effect of composition on the macrostructure of ingots of a low-alloy steel

T. B. Smith, J. S. Thomas, R. Goodall, and R. T. Allsop

SYNOPSIS

Reducing the Si *and* Mn *contents of a* 1·5%Ni–Cr–Mo *steel increases markedly the length of the columnar crystals.*

1952

DURING A SERIES of experiments, in which the effect of casting temperature on the macrostructure of 50-kg ingots of a 1·5%Ni–1%Cr–0·3%Mo steel was being studied, it was observed that the silicon and manganese content of the steel had an influence on the ingot structure which could outweigh that of casting temperature.

In the early stages of this work while the casting technique[1] was still being developed, a number of ingots was produced which, though otherwise satisfactory, had a silicon content much lower and a manganese content slightly lower than intended, i.e. 0·05–0·07%Si compared with an intended 0·20–0·30%, and 0·25–0·35%Mn compared with 0·45–0·65%. It was observed that the length of the columnar crystals in these ingots was much greater than that in ingots cast at the same temperature but having higher silicon and manganese contents. The effect is illustrated in Figs.1*a* and *b* which show the structure of typical ingots cast at 1600°C with normal (ingot no.29), and with low (ingot no.7) silicon and manganese content respectively. The analyses of the two ingots are given in Table I.

It will be seen that whereas the columnar crystals in ingot no.29 are about 1·1in long and occupy about 80% of the ingot volume, in ingot no.7, they are about 2in long and occupy about 99% of the ingot volume.

To confirm this effect a special ingot was cast at 1600°C from a melt consisting of Lowmoor iron, low-silicon pig iron, pure chromium, ferro-molybdenum, and carbonyl nickel, to give the same carbon, nickel, chromium, and molybdenum contents as ingots nos.7 and 29 but with very low silicon and manganese

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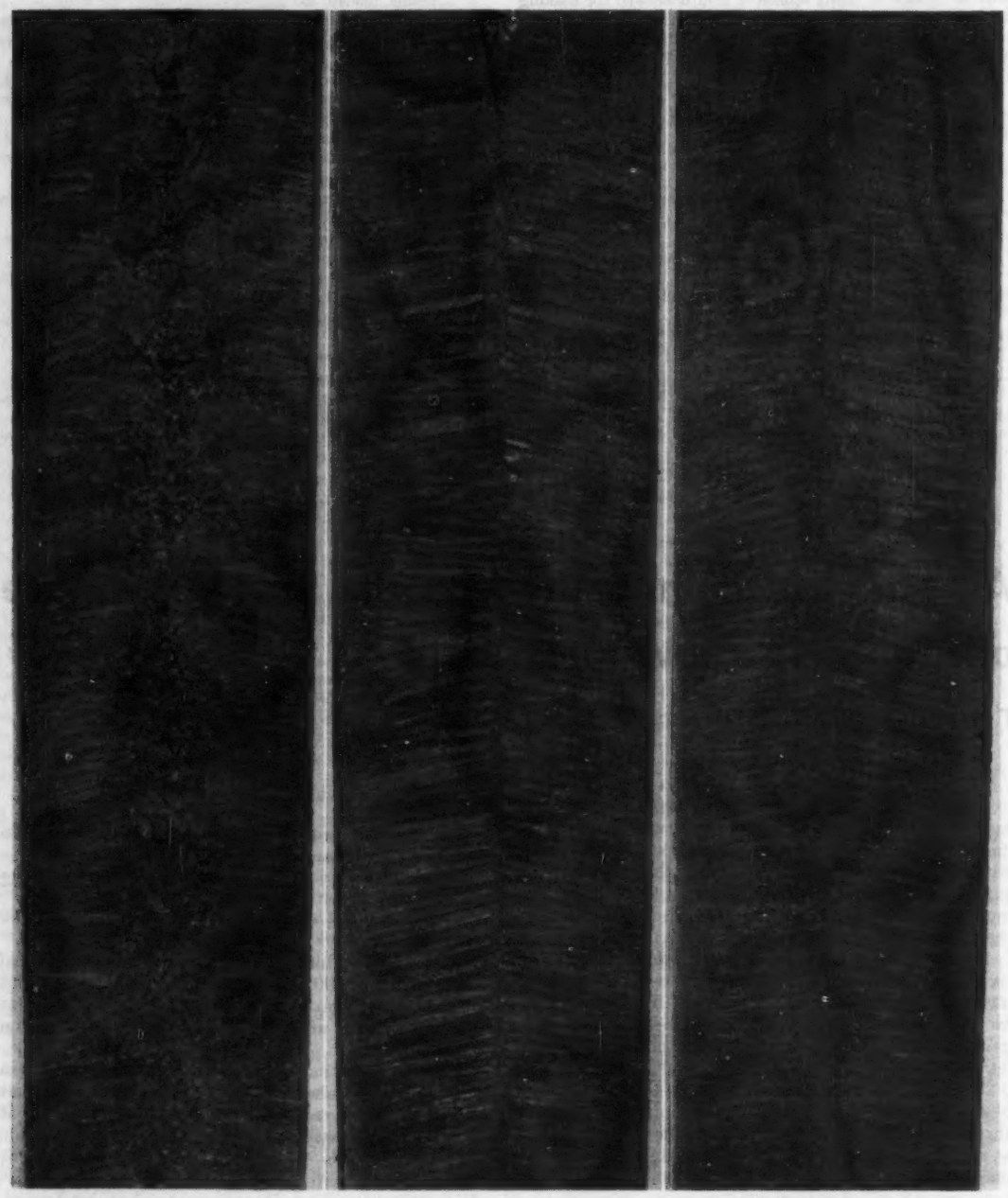
TABLE I Analyses of ingots

Ingot no.	Analysis, % C	Si	Mn	Cr	Ni	Mo	Al	S	P
7	0·32	0·07	0·34	1·01	1·48	0·31	0·025	0·011	0·014
29	0·32	0·30	0·62	1·03	1·50	0·29	0·061	0·012	0·014
63	0·36	0·035	0·065	0·95	1·56	0·35	0·011	...	...

values; its analysis (ingot no.63) is shown in Table I. The structure of this ingot is shown in Fig.2 and is clearly similar to that of ingot no.7.

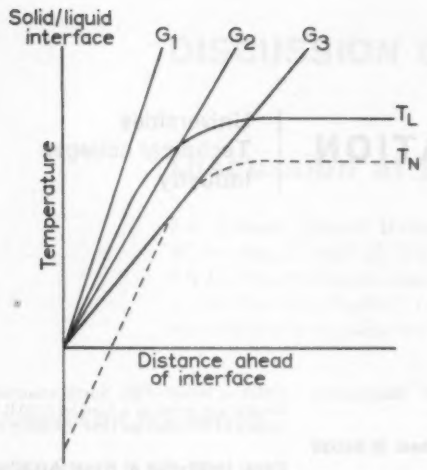
The aluminium contents of the three ingots are such that it might be inferred that the changes in their macrostructure are as likely to be due to differences in aluminium content as to variations in silicon and/or



a b

1 a *Macrostructure of ingot 29 containing normal silicon and manganese contents, and* b *macrostructure of ingot 7, containing low silicon and manganese contents* ×½

2 *Macrostructure of ingot 63, specially prepared to have low silicon and manganese contents* ×½



3 *Constitutional supercooling ahead of advancing columnar front*

manganese. However, enough ingots with high aluminium contents (0·05–0·08%) have been examined, to show that whatever effect aluminium may have it is outweighed by that of the other two elements.

Qualitatively, these results may be explained by consideration of the current theories of ingot structures.[2,3] As the columnar crystals grow they sweep before them a narrow zone in which the liquid is enriched in solute elements and, thus, in which the liquidus temperature, T_L, and concomitantly the nucleation temperature, T_N, is depressed (Fig.3). Nucleation of fresh crystals ahead of the advancing columnar front occurs when the temperature gradient, G, in the liquid falls to a required value, G_3, and further columnar growth is restricted. The effect of decreasing the silicon and manganese content in the steel studied may be to displace T_N and/or T_L in such a way as to delay nucleation ahead of the columnar crystals.

Whether the effect reported here is due primarily to silicon or to manganese or to both elements is not clear from these results; further experiments are in progress to clarify this point and to investigate the mechanism by which the elements promote nucleation.

ACKNOWLEDGMENT

The authors wish to thank Dr T. Emmerson, Director of Research, for permission to publish this note.

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2. L. Northcott: *JISI*, 1941, **143,** 49–91.
3. W. C. Winegard and B. Chalmers: *Trans. ASM*, 1954, **46,** 1214–1224.

Notes for Authors

A 16-page booklet entitled 'Notes for Authors' has recently been published by the Institute. It is divided into two sections, covering 'Publications' and 'Presentation at Meetings' respectively. It is designed to provide prospective authors of papers for publication in the *Journal* or for presentation at one of the Institute's Meetings with answers to all the questions they are likely to ask.

Thus the first section deals with the way in which manuscripts should be prepared, the 'house style' for abbreviations, spelling, punctuation, etc., the best way of preparing illustrations for the printer, and similar problems. The most valuable part of the second section is perhaps that giving recommendations on the preparation of slides for projection at meetings. Guidance is also given on the best way of preparing the verbal presentation of a paper for delivery at a meeting.

Copies of the booklet are available free to Members of the Institute, and may be obtained on application to the Assistant Secretary. Librarians and Information Officers of companies, research organizations, institutions, and teaching bodies, are also invited to apply for free copies.

The British Nuclear Energy Conference

Contents of the Journal 1961

The *Journal of the British Nuclear Energy Conference* is published four times a year: in January, April, July, and October. It consists of papers and discussions on the applications of nuclear energy and ancillary subjects.

The April issue included the Thomas Hawksley Lecture 'Controlled fusion reactions', by Professor P. M. S. Blackett, papers on inspection of nuclear power plant and the *N.S. Savannah*, and other previously unpublished material. The July issue will contain the papers in the Dounreay fast reactor symposium.

The annual subscription is £1 10*s*. for members of the following societies: The Institution of Civil Engineers, The Institution of Mechanical Engineers, The Institution of Electrical Engineers, The Institute of Physics and the Physical Society, The Institution of Chemical Engineers, The Iron and Steel Institute, The Institute of Metals, The Institute of Fuel, and The Joint Panel on Nuclear Marine Propulsion. For all others the subscription is £3.

Requests for detailed information should be made to: The Secretary, BNEC, 1–7 Great George Street, London SW1.

EDUCATION

Universities
Technical colleges
Industry

Waverley Gold Medal Essay Competition

Research is sponsoring the Waverley Gold Medal Competition for 1961. The gold medal, bearing the coat of arms of the late Lord Waverley, will be awarded together with £100 for the best essay of about 3000 words describing a new project or practical development in pure or applied science, giving an outline of the scientific background, the experimental basis, and potential value and application. Specialists in the subject will judge the essays for technical content, clarity of presentation, and style. The essay should be written as if to interest a well informed layman. The aim of the competition is to encourage the scientist in the laboratory and the engineer in the production plant to express their views and translate their ideas into an essay that will be readily comprehensible to other scientists, directors of industrial firms, and others.

A second prize of £50 will be awarded and also a £50 prize for the best entry from a competitor under the age of 30 (if the first prize is won by such a competitor the next best entry will receive this prize). Entries other than the prize-winning may be published in *Research* and a fee will be paid by the publishers. Entry forms may be obtained from the Editor, *Research*, 88 Kingsway, London WC2. The last date of entry is 31 July.

Director of proposed Staff College for Further Education

Mr W. J. Richards, C.B., C.B.E., Director of the Royal Radar Establishment, has been appointed the first Director of the proposed new Staff College for Further Education. He will take up the appointment in July.

The college is intended as a national centre where ideas and experience can be exchanged by senior staff in the educational, and industrial and commercial fields, the universities, and local and central government; and for the study of the significance of education in the scientific climate of today.

Course in applied physics

The College of Engineering Technology, Eastlands, Rugby, is developing a new course based on the study of the fundamental properties of materials. Atomic, electronic, crystal, and molecular structures, with types of bonding and energy relations will be examined; fundamental science and mathematics will be studied as well as liberal studies; and laboratory work is an important element.

The course will be of the sandwich type, extending over five years with six months full-time study and six months industrial training in each year. Entrants must have appropriate passes at O and A levels of the GCE examination or equivalent ONC qualifications.

The course will lead to the Diploma in Technology (Applied Physics) and application has been made to The Institute of Physics for approval of the Diploma as a qualification giving exemption from the Graduateship Examination.

Further details will be supplied on enquiry to the Principal, College of Engineering Technology, Eastlands, Rugby.

Imperial College: Summer school in health physics

The Lecturer in Radiation Hazards has arranged a summer school in health physics (radiation protection) which is to be held in the Department of Chemical Engineering and Chemical Technology, Imperial College, London, from 3 to 14 July 1961. The course is suitable for graduates in science or medicine and should be of interest to radiation protection officers in the universities or industry, medical officers of health, factory inspectors, and the like.

The syllabus will include lectures on basic physics, biological effects of radiation, genetics, external radiation and boneseeking isotope hazards, laboratory design, waste disposal, and the legal aspects. There will be practical work with radioactive materials, and visits to other establishments. The fee is 25 *gns*. There is some accommodation in college halls of residence. Applications for admission should be made to the Registrar, Imperial College, London SW7, from whom further information may be obtained.

College of Aeronautics: one year course in welding

The Institute of Welding and the British Welding Research Association are the sponsors of a one-year course in welding technology for graduates in either metallurgy or engineering, which will take place during the academic year 1961–62. The Diploma in Advanced Engineering will be awarded to students who reach a satisfactory standard.

The course is a compound of mechanical and civil engineering and metallurgy, and aims to produce specialists in welding technology. Special provision is made to strengthen the metallurgist's knowledge of the engineers's field, and vice versa. A vacation course in practical arc and gas welding is part of the programme.

Candidates for the course will be expected to hold honours degrees in appropriate subjects. Selection will be by interview and possibly by written and oral examination. The charges for the year's tuition are: UK students £75, Commonwealth students £250, foreign students £350. Students of British nationality living in the UK are eligible to apply for a grant from the College Bursary Fund; there are also two bursaries offered by the British Oxygen Company: candidates for these will be selected by the Institute of Welding. The residence charge, covering cost of full board during the terms and rent of an individual study-bedroom, is £126 10*s*. Forms of application may be obtained from The Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks.

DSIR research fellowships

Thirty-nine research fellowships were awarded for the current academic year by DSIR and by DSIR on behalf of the North Atlantic Council. Details are given in a booklet 'DSIR Studentships and Fellowships 1961' (HMSO, 1*s*. 9*d*.).

Royal Institution of Naval Architects: summer school

A summer school for teachers of naval architecture has been arranged by the Institution in collaboration with the Worshipful Company of Shipwrights and the Ministry of Education. The school will be held at the College of Aeronautics, Cranfield, from 23 to 29 July inclusive. Applications to attend should be made through the principal of the technical college concerned, to the Ministry of Education, Curzon Street, London W1.

NIFES: refresher and training courses

The National Industrial Fuel Efficiency Service provides a number of courses covering aspects of fuel use and maintenance. The following will take place during 1961:

Sixth annual refresher course for works and plant engineers at the Clarendon Laboratory, Oxford (residence in Brasenose College): 25–29 September

Latest developments in solid-fuel fired combustion equipment in Manchester: 17–21 July, 11–15 September (fee 12 *gns* excluding hotel accommodation)

Industrial oil firing at NIFES Reading office: 19–21 September, 14–16 November, 12–14 December (fee 6 *gns* excluding hotel accommodation).

Details may be obtained from NIFES, 71 Grosvenor Street, London W1. In addition, courses for boiler operators and stokers can be set up in any district provided sufficient enrolments are obtained to form a group. Such courses extend over 21 weeks, combining practical training and home study. The fee is 6 *gns*, well below the actual cost. Details of these courses may be had from the same address.

Regional technical colleges

The List of Regional Technical Colleges in England and Wales is to be revised and a new list designated. Until April 1959 regional colleges were in effect identified with those colleges receiving a special grant for courses in advanced technology. Designation will now depend on other factors. Regional colleges have been envisaged as establishments at which, after the colleges of advanced technology, new advanced full-time and sandwich courses in applied science and technology would be developed. In future no college will be thus designated unless the Minister of Education is satisfied that the college has adequate facilities, staffing, and premises to carry out such work. Geographical considerations will not in themselves influence regional college status. Decisions on designations of colleges for the revised list will be taken after consultation with local education authorities and regional advisory councils. Future revisions will be made when appropriate.

Discussion at the Autumn General Meeting 1960

The Autumn General Meeting of The Iron and Steel Institute was held on Tuesday and Wednesday, 29 and 30 November 1960 at Church House, Great Smith Street, London SW1. At the technical sessions on martensite, held on Tuesday 29 November, Professor A. G. Quarrell (Sheffield University) was in the Chair. The papers presented at these sessions have been published in the Journal, *and the discussions are given below.*

Discussion on martensite

Session 1

At the first session the following papers were presented and discussed:

'The crystallography of martensitic transformations', by *B. A. Bilby*, Sheffield University, and *J. W. Christian*, Oxford University (*JISI*, 1961, **197**, 122–131).

'The morphology of martensite', by *P. M. Kelly* and *J. Nutting*, University of Leeds (*JISI*, 1961, **197**, 199–211).

Dr **Bilby** and Dr **Kelly** presented their papers.

Professor **T. A. Read** (Illinois University): The two excellent papers have presented a fascinating number of questions which I am sure will lead to discussion. There is one particular matter on which I should like to make a few remarks.

Since it might seem that the problem of martensite in the form of plates has been pretty well taken care of by the thin film work of Mr Kelly and Professor Nutting, I should like to turn attention to the matter of martensite needles and suggest that these may be an entirely different brand of animal from martensite plates. I suggest that there may be some use for a lot of the theoretical calculations that have been carried out by my colleagues and by Bullough and Bilby. On the matter of what sort of martensite plates you get when the lattice invariant shear has slipped, it appears from work by Kelly and Nutting that with their plates the lattice invariant shear is twinning. Perhaps that is what a needle is: it is a case when you have slipped, and somehow the plate just grows very much larger in the one direction than in the transverse one.

Briefly, I should like to point out that the basic ideas which have been used in discussing martensitic plates are certainly applicable here. It is just that one has a different boundary condition. The lattice deformation that relates austenite to martensite surely applies in the case of needles as well as plates. In fact, at first sight one might think the problem very simple because the direction of the needles, as reported by Nutting and Kelly, is in fact very nearly along the invariant line of the lattice deformation.

In a sense that theory is too simple, because there is a whole family of such directions making an angle of 46–47° with the austenite cube edge. Also, if one postulated that what occurred in the needle was just the lattice deformation, one could not account for the orientation relationship which was observed. I will not go into the arguments on that in detail except to say that both the direction of the austenite 110 and the direction of the martensite 111 which is parallel to it in each case represents the intersection of two close packed planes. The high symmetry of the lattice deformation is such that one would expect the planes to retain their symmetrical arrangement, and since the angle between the austenite plates is 70° to the vertical and that of the martensite 110 is 60°, they would end up by being 5° out. It may be felt that by some means that could be remedied, but it does not seem physically possible.

I suggest that there is also in this case a lattice invariant deformation which Nutting and Kelly have shown must have slipped because there are no twins, and the reason for the needle-like shape is that there is in any martensitic place a real anisotropy in the sense that there is an invariant line in the plate. In the case of slip, this means that growth along the direction of the plate or the invariant line occurs simply by means of dislocation on a given set of planes. To have growth in the lateral direction, one has to have growth on the slipped plane. This may be difficult, and it may lead, therefore, to a very much greater growth along the direction essentially of the intersection of the lattice invariant deformation with the havoc plane. Thus, the concept of a plane interface would be lost. But I would point out that surely in the case of the forming of a needle there must be consideration of minimizing the mass of the needle and the matrix in the transverse direction. One complicating factor is the volume change on transformation. If there were no volume change on transformation, the condition of an invariant plane would automatically take care of the shape. There would be no change of shape in the needle except for any shearing deformation, which one always has in either plates or needles.

So that to the approximation that one has to dispose of this 4–5° expansion in a transverse direction with a volume change, the calculations which determine the conditions for a lattice invariant strain are essentially the same as those for minimizing the transverse dimensional changes of a needle.

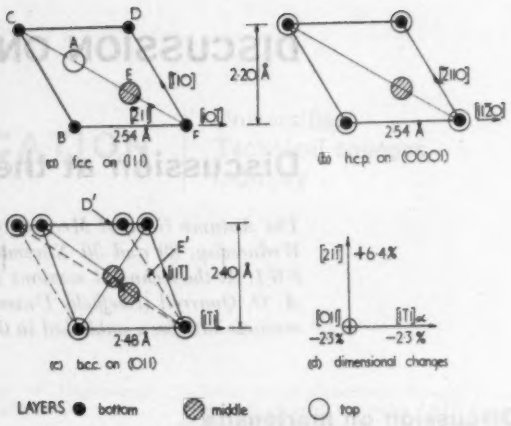
Mr **J. A. Venables** (Cambridge University): I have been doing some work on the nucleation of martensite in an 18–8 stainless steel similar to that used by Mr Kelly and Professor Nutting. Cina[1] tried to show that the hexagonal close-packed ϵ phase found in this steel was an intermediate phase in the transformation from austenite, γ, to body-centred cubic, α, martensite. The resolution of the optical microscope was not really sufficient to test this hypothesis, and I have used the transmission electron-microscope technique to try to show that this is the case.

Figure *A* is an electron-micrograph of a foil prepared from bulk material which was extended about 1% at 78°K. Single stacking faults are seen at A, overlapping faults at B, and a whole sequence of them at C, which is probably a region of ϵ of up to 30 Å thick. The contrast seen at single and multiple stacking faults has been explained in detail by Whelan and Hirsch.[2] A perfect hexagonal phase will be formed if stacking

A *Electron-micrograph of foil prepared from bulk material and extended about 1% at 78°K*

faults are produced on every other (111) plane in the austenite, and the wider ϵ plates ($\sim$1000 Å thick) tend to be more perfect than the thin ones. In almost all specimens the body-centred martensite was found to nucleate at intersections of the (not necessarily perfect) ϵ plates. There was also some nucleation of α from the ϵ, not at intersections, but there was

B *α-Martensite plate with $\{522\}_\gamma$ habit plane showing nucleation*

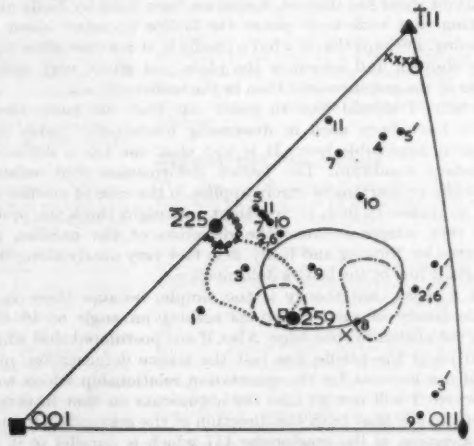


C *Atom movements in the nucleation process*

no nucleation from γ itself not in conjunction with the ϵ phase.

Figure *B* shows an α martensite plate with a $\{522\}_\gamma$ habit plane which has nucleated at the intersection of the two ϵ plates ϵ_1 and ϵ_2, within the plate ϵ_1. The α plate has proceeded to the grain boundary B and has faulted the next grain heavily.

Figure *C* shows what I consider to be the atom movements in the nucleation process. Figure *C*(*a*) represents the austenite on (111), which is deformed into the ϵ-martensite of Fig.*C*(*b*) by a shear on every second (111) plane of $a <\bar{2}11>/6$, i.e. by moving atom *A* to positions *B*, *C*, or *D*. The α lattice can be formed from ϵ by shearing the ϵ lattice on the system $(21\bar{1})$ $[\bar{1}11]_\alpha$ in either direction. Such a shear can be produced at the tip of an ϵ plate which has another $\{111\}_\gamma$ plane as habit plane. Recently Otte[3] has shown that in a 28 Cr 150 alloy, which has the same habit plane variant $(252)_\gamma$ as the stainless steel for the orientation relationship shown in Fig.*C*, the slip (or twinning) system is also $(21\bar{1})$ $[1\bar{1}1]_\alpha$, supporting this mechanism of formation. A similar calculation for this stainless steel also gives very good agreement with the experimentally determined habit plane. Reed and Greeson[4] of the National Bureau of Standards, Colorado, reported that they had examined a similar steel after quenching by an etching technique and had also found that the martensite appeared at the intersection of hexagonal plates. They found that most of the martensite



● Poles predicted by possible mechanical deformation modes
○ The $\{111\}_\gamma$ habit plane prediction
For a detailed discussion of the predicted poles and the scatter regions shown, *see* ref.3

D *Predicted and observed habit planes*

plates had a $\{259\}_\gamma$ habit plane, so that this nucleation mechanism may also be applicable to the $\{259\}_\gamma$ transformations as well as those with $\{225\}_\gamma$ habit already discussed.

Dr **A. G. Crocker** (Battersea College of Advanced Technology): Dr Bilby has referred briefly to some of the results we obtained on the crystallography of the martensite reaction using a digital computer. In all, we obtained information relating to over 3000 different habit planes, the computer taking only a few hours to perform the necessary calculations.[6–7]

In order to analyse these results systematically we examined initially those habits predicted when the lattice invariant or dislocation deformation occurs by means of one of the normal mechanical deformation modes of the martensite and austenite structures. The poles of these habits are plotted and numbered on the standard austenite stereographic triangle shown in Fig.*D*, where the regions of habit plane scatter observed by various experimental workers are also indicated. The poles are for interfaces with zero dilatation; it was found that uniform dilatations of up to $\frac{1}{2}$% did not greatly influence the results. All but three of the poles lie outside the scatter regions. Pole 8 corresponds to the $\{3, 10, 15\}_\gamma$ prediction of Wechsler, Lieberman, and Read[8] and other workers,[9, 10] pole 3 corresponds to twinning of austenite and pole 9 to $\{123\}$ slip of martensite. The mechanisms resulting in poles 3 and 9 are unlikely to occur in practice and the predictions thus show that the observed habit planes and scatter cannot be explained by using these simple shear modes.

More general shear systems, in which the shear occurs either on two planes in a given direction or in two directions on a given plane, enabled the $\{111\}_\gamma$ habit, observed by Entwisle[11] in pure iron, to be explained but not the $\{225\}_\gamma$ and $\{259\}_\gamma$ habits or the large scatter of results. It would be interesting to know whether thin film work on pure iron could be carried out in order to confirm the $\{111\}_\gamma$ habit and to determine the internal structure of these martensite plates.

If even more general shear systems are allowed, involving shears on more than one plane in more than one direction, all the observed habits can be predicted. However, this type of generalization introduces complications into the motion and structure of the interface and does not result in an entirely satisfactory explanation of the observations.[7]

By fixing the lattice invariant shear mode and allowing much larger dilatations of the interface Bowles and Mackenzie[9] were able to explain the $\{3, 10, 15\}_\gamma$, $\{259\}_\gamma$, and $\{225\}_\gamma$ habits. The work of Kelly and Nutting supports their assumptions but does not explain the scatter of the results; variation of the dilatation gives a line on the stereogram, not a two-dimensional scatter region.

These present results thus support the veiw of Bilby and Christian that it is necessary to vary both the lattice invariant shear mode and the uniform interfacial dilatation in order to explain all the observations. Another way in which a two-dimensional scatter of results can be obtained is by the introduction of a non-uniform dilatation into the interface, and some progress is at present being made towards generalizing the theory in order that this possibility may be examined.

Dr **Kelly** (in reply): Dr Crocker's comment on the observed scatter in the habit planes depends to a large extent on what feature of the martensite plate is chosen as the trace of the habit. A number of determinations have been based on the martensite 'mid-rib'. In our paper we suggested that the 'mid-rib' in fact represents the plane of contact between two martensite plates. If the two plates have the same orientation relationship and habit, then the plane of contact will be parallel to the common habit plane. However, the thin foil study of martensite shows that the plates often have different orientations with adjacent habit planes; for example two plates with habit planes $(225)_\gamma$ and $(259)_\gamma$. In this case the plane of contact is likely to be the unrotated plane, which is common to both plates, namely $(111)_\gamma$. If this explanation of the 'mid-rib' is correct, then determinations of the habit plane based on the 'mid-rib' should show a $(111)_\gamma$ habit, as has been reported in the literature.

The other common criterion for deciding where the trace of the habit plane lies, is to take the longest direction in the section of the plate. If such a plate is joined to another of differing orientation in the manner postulated above, one long edge of the plate will be parallel to the true habit plane and the other edge will be the plane of contact between the two plates. Thus the longest direction will be intermediate between the trace of the habit plane and the trace of $(111)_\gamma$. The scatter in the habit plane normal to the Bowles-Mackenzie habit line can then be explained, since a habit plane determined by experiment in this way will lie between $(111)_\gamma$ and $(259)_\gamma$. The observed region of scatter (*see* Fig.*D*) is in fact found to be on the $(111)_\gamma$ side of the Bowles-MacKenzie habit line, as this explanation predicts. More work is necessary before it is known whether the above explanation of the 'mid-rib' is correct. However, a satisfactory explanation of the 'mid-rib' must be found and a standard method of determining the habit plane adopted, before the true significance of the observed scatter in the habit plane can be determined.

Dr **Bilby** (in reply): I agree with Mr Kelly about the interpretation of habit plane measurements. Previously we have thought about austenite meeting martensite, but it is obvious that what happens in many cases is that martensite meets martensite. So we have not only to think about the compatibility between martensite and austenite, but also about that between two regions of martensite not necessarily of the same habit. This is a theoretical problem that needs investigating.

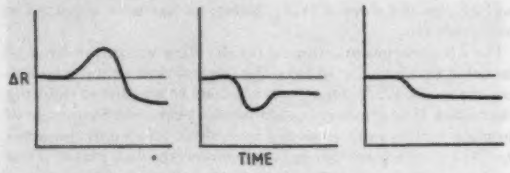
Professor **Robert F. Mehl** (Carnegie Institute of Technology; US Steel Corporation): I would like to add a minor point or two, particularly with respect to the morphology of precipitates in solid/solid reactions.

While plate-shaped precipitate crystals are familiar in such reactions, true needles are occasionally observed, and the reasons for this morpholoogy are as mysterious in these cases as in the formation of martensite. A good many years ago Marzke and I[12] observed that true needles form along the [556], axis in beta brass when alpha brass precipitates under some conditions of heat treatment, while under others true plates form. Why such an unusual axis should be chosen as yet no one knows. Also Geisler[13] observed that the precipitate from the Al-rich solid solution of Cu in Al takes the form of laths in an early stage of ageing. There are still very basic questions in this field of crystal morphology unanswered, indeed the field has been much neglected in recent years.

Last autumn at the annual meeting of the American Society for Metals in Philadelphia, Zackay of the Ford Company research laboratory presented, at a symposium (to be published shortly in book form), a series of photomicrographs showing the morphology of martensite plates in an Fe–Ni alloy which had been deformed just before martensite was caused to form; the martensite plates sometimes cross slip bands, and twins; often on crossing an area heavy with slip bands the martensite plates take on a very ragged appearance; a good explanation of this is lacking.

Finally I should like to report to you on some of the work done by Professor E. Scheil and his students at Stuttgart. Some years ago Bunshah and I measured the rate of formation of a martensite plate in an Fe–Ni alloy, using an oscilloscope and a circuit which would detect a change in resistivity with a sensitivity of 10^{-9} s; it was found that the rate of propagation was about equal to that of sound, in this alloy. Scheil has used this kind of technique (private communication, as yet unpublished), varying the alloy content, and studying the effect of a magnetic field. In brief, Scheil found three types of oscilloscope curves, plotting the change in resistivity against time (Fig.*E*).

In a given sample, under various conditions, one, two, or all three of these curves were observed. The first of these is the same as that Bunshah and I found, and the time period is the



E *Three types of oscilloscope curves*

same. But what the significance of the occurrence of the several forms of curve might be is difficult to see: could there be more than one form of martensite in this alloy? It doesn't seem very likely.

Professor **J. Nutting** (Leeds University): The comments by Dr Mehl lead to a question that I should like to ask Dr Bilby and Dr Christian. The ideas put forward by Bowles and Mackenzie suggest that there could be, from the mathematical treatment of the problem, a two-stage reaction, but, of course, they never attempted to give this any physical significance.

In view of the comments by Dr Mehl and the ideas put forward by Bowles and Mackenzie, I should like to ask Drs Bilby and Christian whether they think there is any physical reality to this concept of a two-stage or even more complicated mechanism; that is, that we go from the unstable austenite to the martensite via some metastable stage.

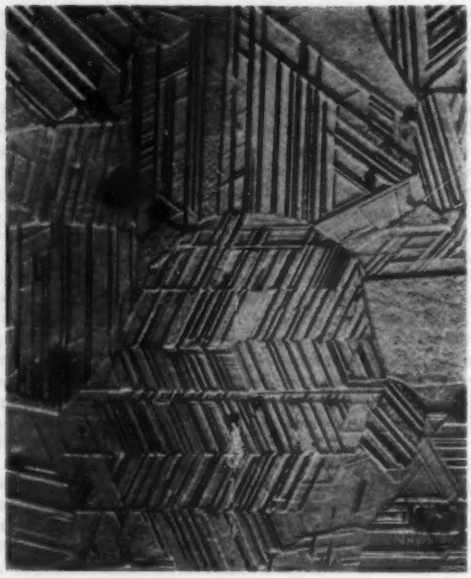
Dr **Christian** (in reply): There are two senses in which we can take the question. One is the formation of an intermediate product prior to nucleation of martensite, and Mr Venables has shown us that this does indeed happen in some transformations. I think, however, that Professor Nutting is asking whether the usual factorization of the lattice deformation into a shape deformation and an 'invisible' deformation has any physical significance. In other words, does the lattice produced mathematically by applying (say) the shape deformation to the parent exist physically as a transitional region between the parent and the martensite? I think this is very improbable.

What we are really doing in the crystallographic analysis, as Dr Bilby showed, is producing a matching condition which ensures compatability of lattice and shape deformations. The two lattices will then fit together at a fairly sharp interface which can readily move. It is geometrically possible for there to be two successive sharp interfaces, but this will not improve the matching and will introduce the extra energy of the intermediate region. Moreover, that one of these two separated interfaces at which the shape deformation occurs will be fully coherent, and might be expected to be less mobile; in a sense, it is the discontinuities which give the interface its glissile nature. So it seems to me that much of the point of the matching condition is lost if we assume that the purely mathematical procedure of factorization has, coincidentally, a physical significance.

In the more detailed models, great care has to be taken before discontinuities in the interface are ascribed properties which belong to defects *within* a lattice. This is exemplified, for example, by consideration of the definition of the Burgers vectors of the interface discontinuities when these are assumed to be dislocations.

Dr **Bilby** (in reply): One cannot make an *ex cathedra* pronouncement about the deformation sequence, for the analysis may be carried out with any formal order for the deformations. We have to return the question to the experimentalists and ask if there is any evidence that there are two interfaces, one following the other. If so, we have evidence of a physical separation of the two processes.

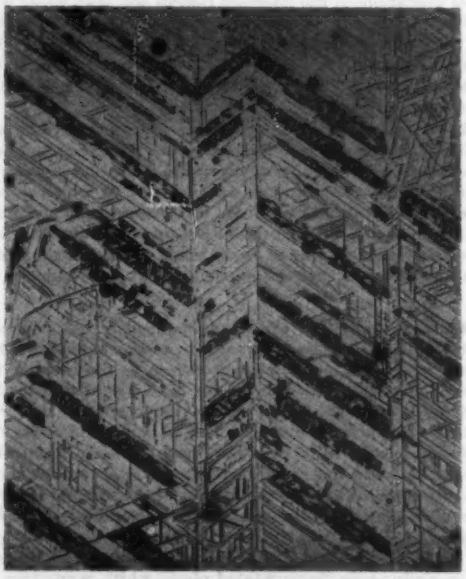
Professor **Nutting** (in reply): There is no direct experimental evidence at the moment for the two interfaces. However, once a martensite needle stops growing it is difficult for it to re-start. This phenomenon could be explained on the two-interface



F *Alloy containing* 14%Cr, 14%Mn, *and* 0·1%C *water quenched from 1050°C*

model by assuming that during growth the two interfaces are moving separately and when growth stops the interfaces come together. Before further growth can occur the interfaces must separate and this is likely to be a process requiring a high energy.

Mr **Venables:** There is some evidence for a two-stage process of growth of α-martensite in stainless steel which can be explained with reference to Fig. *B*. Many of the martensite plates have steps in the interface along the $(111)_\gamma$ plane which is the habit plane of the nucleating phase, as shown at C. These steps may



G *Presence of α-martensite needles which have been nucleated with ε lamellae*

correspond just to deformation caused by the formation of the α plate; but they may indicate where the first deformation $\gamma \rightarrow \epsilon$ has overshot the existing α martensite boundary and where the subsequent $\epsilon \rightarrow \alpha$ transformation has not been completed. In the latter case they would be evidence for a two-stage growth process.

Professor **R. W. K. Honeycombe** (Sheffield University): I would like to pursue a matter which Mr Venables raised earlier in connexion with the nucleation of martensite, in particular to consider the effect of varying the composition of the austenite. Today we have been discussing mainly the transformation of high-carbon low-alloy austenite which seems to have a much higher stacking fault energy than alloy austenites with low carbon contents. Mr Venables has pointed out that in alloy austenites stacking faults may play a big part in the nucleation of the martensite plates, a point of view with which I agree.

The question rather hinges on the incidence of hexagonal close packed ε-martensite, which, although well-known in the iron–manganese system,[14] is also found in 18–8 austenitic steel and in many other austenitic alloys[15, 16] of low carbon content. I think that all these alloy austenites have lower stacking fault energies than plain carbon austenite, and it is this greater tendency to form stacking faults which encourages the formation of ε-martensite by providing suitably oriented nuclei of the same crystal structure. Furthermore, the ε-martensite is subsequently able to nucleate the normal α-martensite.

These features of the martensitic transformation of austenite are particularly well revealed in the manganese–chromium austenites which have been studied recently at Sheffield by Sanderson.[17] Figure *F* is from an alloy containing about 14%Cr, 14%Mn, and 0·1%C which has been water quenched from 1050°C. The austenitic structure is apparently heavily twinned, but in fact, the majority of the lamellae on {111} planes are ε-martensite, as X-ray examination clearly shows. Other specimens of the same steel after similar heat treatments show also the presence of α-martensite needles which have been nucleated within the ε lamellae (Fig.*G*).

The sequence suggested for the transformations is austenite with stacking faults $\rightarrow$ε-martensite$\rightarrow$α-martensite when the stacking fault energy of the matrix is low. However, if this energy is raised, e.g. by addition of carbon, then the tendency is for the α-martensite to form directly from the austenite.

Dr **Christian:** I should like to make a brief point about {225} transformation in connexion with something which Dr Crocker said about the possibility of using non-uniform dilatations in the habit plane.

Dr Wayman, of Illinois, has recently been making some accurate measurements on {225} plates in an alloy steel, and his results seem to confirm almost exactly the predictions of Frank's model. This is in contrast to most of the previously reported measurements on {225} martensite, the detailed results of which fit the Bowles-MacKenzie analysis rather better than Frank's analysis. The essential difference in the two treatments is that in Frank's model the habit plane contains one macroscopic direction of perfect fit and a direction of maximum misfit normal to this, whereas in the Bowles-MacKenzie theory there is uniform misfit in all directions. Thus if these experimental results are substantiated, we have good evidence of a case in which the habit plane is not determined by an exact matching condition, but the mismatching is not uniform in all directions.

Dr **A. P. Miodownik** (Battersea College of Technology): The dilation parameter mentioned in several theories of martensite formation provides a convenient method of improving the predicted habit plane, but does not seem to be related in any way to the changes in volume known to occur during the transformation. In particular, the changes in the postulated dilation parameter with temperature are of opposite sign to the known changes of volume with temperature. Would the authors care to comment on this apparent anomaly?

Mr **Venables:** If I may answer the second question, the volume and lattice parameter changes accompanying the transformation are not detectable by electron diffraction, i.e. the changes must be less than about ¼%.

Mr **J. H. Woodhead** (Sheffield University): I wonder whether Mr Kelly has obtained any optical micrographs of the material which he studied by thin film techniques. It would be satisfying to know whether or not these differences in transformations which were observed in the thin films were also observable by normal microscopy.

Dr **Kelly:** At least one specimen of each alloy and heat-treatment was examined in the optical microscope. The structure observed optically agreed in every case with that seen in the electron microscope.

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Session 2

At session 2 the paper **'The kinetics of the martensite transformation in iron alloy'**, by *W. S. Owen* and *A. Gilbert*, Liverpool University (*JISI*, 1960, Oct., **196**, 142–149), was presented and discussed.

Professor **Owen** when presenting his paper said: We have come to the view that it is better to emphasize the criterion proposed by Bilby and Christian; namely, that a martensite reaction is one involving a shear tilt on a plane free surface. The difficulty with trying to apply the single criterion that the transformation should be diffusionless is that a number of transformations have been identified in which it is extremely unlikely that diffusion over more than one or two lattice distances is involved but in which no surface tilts are produced. Such transformations are the gamma to alpha change in pure iron at moderately fast cooling rates, the 'massive' transformations in copper base alloys described by Massalski,[1] and the decomposition of metastable beta-brass to 'massive alpha' observed by Hull and Garwood.[2]

In the paper we point out that the big difference in driving force at M_s between the low-alloy binary systems on the one hand and the iron–carbon and highly alloyed stainless steels on the other is contrary to the predictions from any of the nucleation theories. We now believe that the nature of the transformation is quite different in the two cases. The transformations occurring at relatively high temperatures in the low-alloy substitutional solid solutions are of the 'massive' variety whereas the transformations at lower temperatures in the other systems produce a surface shear and so are truly martensitic. The evidence for this assertion is:

(i) There is a marked difference in the metallography of the transformation product. For example, martensite plates can be seen clearly in a transformed 30 at-% Ni–Fe alloy but in an alloy containing less than 10%Ni no plates can be distinguished.

(ii) The high temperature transformation can be depressed by increasing the cooling rate which strongly suggests that the transformation is thermally activated; the low temperature transformation cannot be depressed. Experimentally it has not been possible to suppress the high temperature transformation in iron–nickel (less than 15%Ni) and iron–chromium alloys but with relatively pure iron a sufficiently rapid cooling rate can be achieved. With a cooling rate of about 5 500°C/s the transformation occurs at 540°C which is probably a true martensite reaction. This is supported by the fact that the M_s temperatures for iron–carbon alloys extrapolate to this temperature at zero carbon. These experimental data will be presented in detail elsewhere. Entwisle[3] and others have demonstrated that iron specimens transformed during an extremely rapid quench do produce surface shear markings.

(iii) The high temperature transformation occurs at quite different temperatures in the iron–nickel, iron–chromium, and iron–silicon systems and yet in all cases the driving force is about 40–50 cal mol^{-1}. By contrast, the true martensite reactions have a driving force of the order of 300 cal mol^{-1}.

(iv) There is a possibility that there is an inflexion in the M_s *v.* nickel content curve for the iron–nickel series. This possibility has been suggested by Haynes.[4]

Massalski,[1] discussing massive transformations, suggests that they occur by a mechanism that has some of the features of a martensite reaction and some of growth by diffusion. In the iron base alloys there is nothing to suggest a similarity to the martensite shear and we feel that growth of the alpha phase is most probably by short range diffusion across a high angle interface.

This distinction between massive transformations and martensitic transformations in iron alloys has an important bearing on the attempts to devise empirical formulae for the M_s temperature of complex alloy steels. This point is elaborated in the subsequent discussion.

Mr **J. H. Woodhead** (Sheffield University): There is little in the paper that one can criticize, and so perhaps I might mention first the only point upon which I can seriously disagree with the authors' statements. In discussing the effects of deformation is it said that all transformations are assisted by plastic deformation. However, Soviet workers[5] have shown that there are two types of behaviour for martensite transformations: (i) alloys in which transformation is always retarded by deformation, and (ii) alloys in which transformation is stimulated by small amounts of deformation and retarded by greater deformation.

So far as the work on driving force is concerned, I think the paper gives an extremely valuable summary, but I must admit that I feel a little unhappy about the overall picture which is presented. One gets the impression that workers in this field produce rather elaborate expressions for the driving force but, in general, leave a number of disposable parameters which are then selected to fit the experimental results. Such an approach has decided limitations for, if a sufficient number of disposable parameters are available, one can fit anything. However, it seems clear that a measure of progress has been achieved by using the regular solution model rather than the ideal solution model which is obviously not applicable. In this connexion I found the suggested correlation between metallographic appearance and driving force particularly interesting; however, in view of Professor Owen's additional remarks this morning, some modification of this idea may be needed.

I wonder whether the authors are satisfied with stating that there is a constant driving force for carbon martensite now that Mr Kelly and Professor Nutting have demonstrated that two different kinds of martensite are formed in iron–carbon alloys and that the amounts of each kind depend on the carbon content.

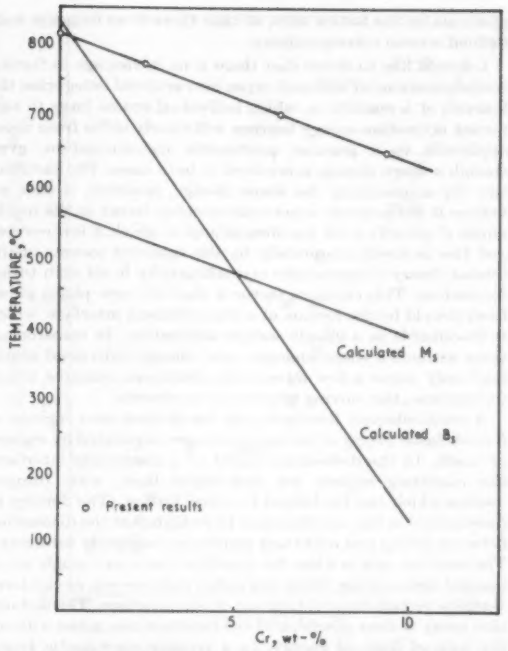
On the nucleation problem, the paper presents all the relevant information and gets us as far as we can go at the moment. However, I have one or two comments to make about the section dealing with the progress of transformation.

I notice that, in the paper, a relationship is presented relating the amount of transformation to the degree of undercooling and that this has an exponential form. Brook, Entwisle, and Ibrahim[7] found a linear relationship between transformation and temperature for a considerable range of transformation. The two equations do not appear to be compatible. In addition, Brook *et al.* found that the slopes of their straight lines differ significantly for different steels so that, even if their relationship is not the right one, it seems improbable that a single equation could fit all results.

I was a little disappointed to find that, in the paper, the question of bursting was treated very briefly because in some highly alloyed martensites the transformation progresses very largely by bursting. At the present time, Mr Brook and I are studying some steels containing about 20%Ni and with carbon contents of around 0·5%. We find that transformation usually begins with a burst and that numerous additional bursts occur during further cooling. These bursts are of variable magnitude and neither their magnitude nor their temperatures are reproducible. The bursts are accompanied by very distinct audible clicks and by easily measurable temperature rises. As much as 10% transformation may occur in a single burst and temperature changes of up to 8°C have been observed.

Thus, bursting is a major form of transformation in these materials and it clearly requires serious consideration from the theoretical point of view. There are certain effects of cooling rate on these phenomena but I will leave this for Mr Brook to deal with later in the discussion.

In addition we find that the athermal transformation occurring during cooling has not the usual regular variation with temperature. The general progress of the transformation is as follows. First we get a burst and this is followed by a relatively quiescent period during which little, if any, transformation occurs. Then the amount of martensite increases rapidly with falling temperature but the rate of change gradually falls off and another quiescent period follows. There may then be



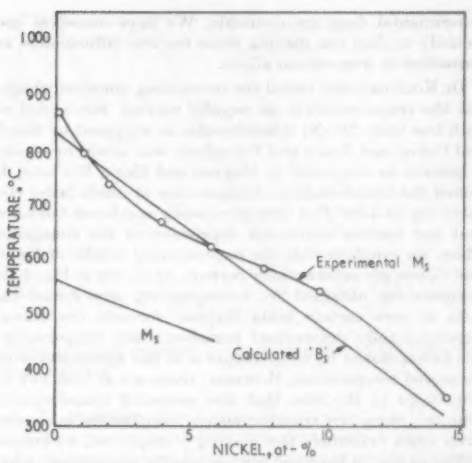
A *Comparison of experimental M_s and Haynes' calculated M_s and B_s temperatures*

another burst followed by a similar changing rate of transformation. In some cases we find a succession of fluctuating transformation rates which are not separated by bursts. There is no evidence that these phenomena are attributable to a series of very small bursts. It appears that there are still many aspects of the martensite transformation which need investigation both experimentally and theoretically.

The following contribution sent by Dr **L. Kaufman** (Manufacturing Laboratories, Inc., Cambridge, Mass.) was read by the **Chairman:** The authors are to be congratulated upon their fine review of the kinetics of martensite transformation. I would appreciate their comments on the following points.

First, Gilbert and Owen (ref.12*) have carried out a study of the effect of cooling rate on M_s in Fe–Ni and Fe–Cr alloys which is of extreme significance. Measurements of the M_s for Fe–Ni alloys containing between 5% and 34%Ni at cooling rates between 1°C/min and 100°C/min have been carried out (refs.5 and 7). The results of these measurements are in very good agreement. Recently, however, it has been suggested[8, 9] that, for alloys containing less than 20%Ni, the results of these measurements (refs.5 and 7) are incorrect. Haynes[8] and Clark[9] suggest that, for less than 20%Ni, Kaufman and Cohen (ref.7) actually measured the B_s temperature rather than M_s. Kaufman and Cohen suggested that, since diffusion in Fe–Ni austenite is slow, and M_s was apparently insensitive to cooling rate, M_s had been measured rather than B_s. How do the recent measurements carried out by the authors of the effect of cooling rate on M_s in Fe–Ni alloys bear on this question?

Second, in the section dealing with calculation of the driving force by the more accurate method suggested by Kaufman and Cohen (ref.7), the authors suggest that this method can only be applied successfully to the iron–nickel systems where 'certain difference terms are small'. This method has been successfully applied to Fe–Cr and Fe–Ni–Cr alloys (ref.11), as is pointed out by the authors. In addition, the method has been applied with considerable success in dealing with the chemical driving



B *Comparison of experimental M_s and B_s calculated by Haynes formula*

force for martensitic transformations in titanium-base alloys.[10] It has been found that the driving force at M_s in these alloys is about 50 cal/mol. Recently,[11] Dr Yen Chein Huang of Tohoku University has measured A_s in Ti–Zr and Ti–Nb alloys. His measurements show that $T_o = 1/2\ (M_s + A_s)$ and that the driving force at M_s is about equal to the driving force at A_s, in agreement with observations on Fe–Ni alloys (ref.7).

Third, recent experiments[12, 13] at our laboratory on the effect of hydrostatic pressure on the potency of martensitic embryos having a bcc structure have borne out the predictions of the 'strain nucleus theory'. The theory (ref.1) predicts that, if austenite containing bcc embryos is exposed to high pressures at temperatures above the freezing-in temperature, T_f, and quenched under pressure to $T < T_f$, the embryo size will be decreased. If the pressure is then removed and the specimen is cooled at atmospheric pressure, a martensite start temperature, M'_s, will be observed. Since the size of the embryo is decreased by the pressure treatment, M'_s, will be lower than M_s observed when no pressure treatment is used. A corollary to this prediction is: if an austenite containing 'shrunken embryos' is heated above T_f at atmospheric pressure, the embryos will expand to their usual size and, on subsequent quenching, the normal M_s will again be observed.

These predictions were corroborated by experiments on an Fe–32·4%Ni alloy ($M_s = 130$°K) by using heat-treating pressures of 25 and 50 kilo bars. T_f was found to be about 550°C, and M'_s was determined to be below 80°K.

Professor **Owen:** According to the published data, the free-energy change accompanying the martensite transformation in iron–carbon alloys is not sensitive to changes in the carbon content. Thus, no difference in the driving force for plate and needle martensite formation has been detected so far. However, the thermodynamics of interstitial solid solutions has not been developed to the same degree of refinement as for the substitutional alloys and possibly future theoretical developments will enable the difference to be detected.

Of course, we agree that the burst phenomenon is very important in certain alloys. It received only scant mention in our review because the space available was limited and it appears to us that bursting is not a major factor in the majority of transformations.

We did not wish to imply that the most recent version of the Kaufman-Cohen method (utilizing the Svechinkov-Lesnik expression) for evaluating the free-energy change could be applied only to the iron–nickel system. As Dr Kaufman points out, it can be applied to the iron–chromium system (a point mentioned in our paper), and to a variety of other systems. In fact, it can be applied to any system for which the relevant

* References in parentheses refer to those in the original paper.

experimental data are available. We have ourselves used it recently to find the driving force for the diffusionless transformation in iron–silicon alloys.

Dr Kaufman also raised the interesting question whether or not the transformation on rapidly cooling iron–nickel alloys with less than 20%Ni is martensitic as supposed by Kaufman and Cohen and Jones and Pumphrey and others or whether it is bainitic as suggested by Haynes and Clark. We have determined the transformation temperature at much faster cooling rates (up to 5500°C/s) than previously employed but failed to find any further significant depression of the change point. Thus, we conclude that the experimental results of Kaufman and Cohen are substantially correct. As shown in Fig.*A* the M_s temperature obtained by extrapolating iron–nickel–carbon data to zero carbon using Haynes' formula lies below the experimentally determined transformation temperature but the extrapolated B_s temperature is in fair agreement with the measured temperature. However, there are at least two major objections to the idea that the measured transformation is bainitic. Since the transformation temperature is unchanged even when extremely fast cooling is employed, no long-range diffusion can be involved but, as usually understood, a bainite reaction requires lattice diffusion. Secondly, the apparent agreement between the transformation temperature and the extrapolated B_s has been found not to hold in the other binary systems we have investigated. For example, the results for the iron–chromium system are shown in Fig.*B*. The measured transformation temperature does not agree with the extrapolated M_s but neither does it agree with the extrapolated B_s. Thus, it is concluded that the transformation on rapidly cooling iron–nickel alloys with less than 20%Ni and iron–chromium alloys is neither martensitic nor bainitic. As outlined in the verbal introduction to our paper, we believe the transformation to be massive.

Mr **R. Brook** (Sheffield University) presented a review of a previously published paper[14] relevant to the discussion and which, in part, had prompted further work on the burst phenomenon of the martensite transformation. Continuing he said: This work has indicated that the size of burst in a given alloy is influenced by the cooling rate, with the larger bursts occurring at slow cooling rates.

I cannot agree with Professor Owen in discounting the burst transformation so lightly. We have obtained a mixture of burst and athermal transformation in a coarse-grained alloy having an M_s above room temperature. The nature of the transformation in fine-grained material and the upper temperature limit required to eliminate the burst component have yet to be investigated.

Dr **J. W. Christian** (Oxford University): When we originally thought of separating martensitic transformations from others by the observation of a shape change, we had in mind that there must be such a change if the atoms move less than an interatomic distance relative to their neighbours, and that there is unlikely to be a shape change if they move more than an interatomic distance. The theoretical significance of a shape change is that it implies a lattice correspondence, so that labelled rows or planes of atoms (strictly, of lattice sites) in the parent change into similarly labelled rows or planes in the product. In certain martensitic transformations, ordered phases transform into ordered phases, as is necessary if there is a correspondence and if atoms move less than an interatomic distance.

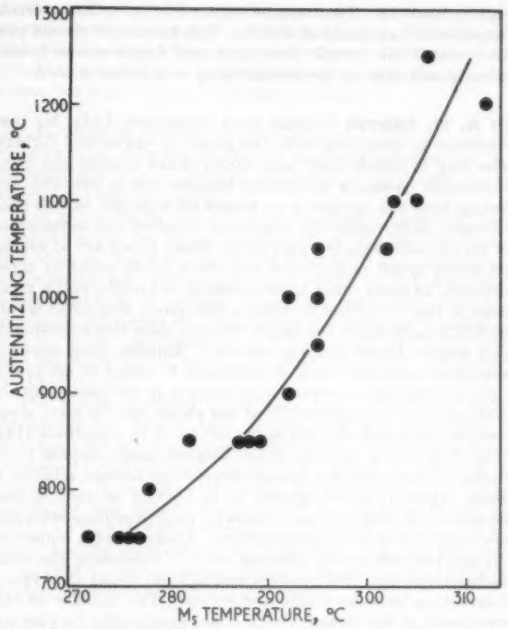
We now know, however, that shape changes are produced during some ordering reactions, and in the early stages of some precipitation reactions. Thus our concept of a growth mechanism which involves a shape change must be extended to include cases in which individual atoms move up to a few interatomic distances during transformation; this seems to cover all known examples with the possible exception of bainitic reactions, which I shall discuss separately. In a sense, we may think of the shape change as still indicating a lattice correspondence, but we now allow interchanges of atomic positions on the lattice sites, so that there is no longer a well-defined atomic correspondence.

I should like to stress that there is no advantage in forcing transformations of different types into artificial categories; the kinetics of a reaction in which individual atoms have to surmount activation energy barriers will clearly differ from those applicable to a genuine martensitic transformation, even though a shape change is involved in both cases. The justification for emphasizing the shape change, however, is that we believe it indicates an important common factor in the mechanism of growth in all transformations in which it is observed, and this is shown empirically by the apparent success of the formal theory of martensite crystallography in all such transformations. This common factor is that the new phase grows from the old by the motion of a semi-coherent interface, which is describable as a glissile surface dislocation. In transformations without a shape change, even though individual atoms may only move a few interatomic distances (massive transformations), the moving interface is incoherent.

A semi-coherent interface may be divided into regions of forced elastic fitting of the two structures, separated by regions of misfit. In the dislocation model of a martensite interface, the misfitting regions are dislocation lines, with Burgers vectors which can be defined in either lattice. (The density of dislocations in the interface may be so high that the distinction between fitting and misfitting regions is completely arbitrary.) The simplest case is when the interface contains a single set of parallel dislocations, which are either pure screws, or else have Burgers vectors which stick out of the interface. The dislocation array is then glissile, and the interface can move without the help of thermal energy. In a genuine martensitic transformation, the interface can move very fast; in order, disorder, or segregation processes, it may move quite slowly, being limited by the time taken for a few atomic jumps.

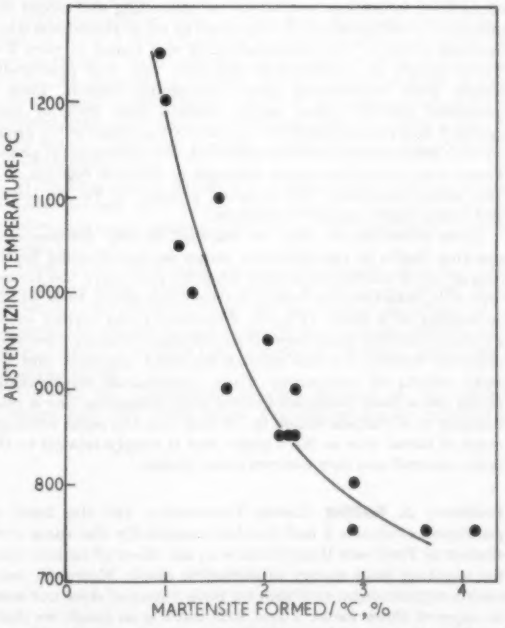
This leads to the question of whether the observed shape change necessarily indicates that the interface is of this type. In principle, we can also have a semi-coherent interface of the type discussed by van der Merwe, in which parameter misfits parallel to the interface are corrected by dislocations. The dislocations then have Burgers vectors lying in the interface, and as the interface moves, these dislocations must climb. The motion of the interface is non-conservative, since the number of atoms incorporated into a new region of product is different from the number in the region of parent swept by the interface. Now, if the correspondence is fully maintained, the shape change given by this type of growth process is an invariant plane strain, just as in a martensitic reaction. The growth process involves the long range diffusion of vacancies or interstitials through distances of the order of the distance moved by the interface itself, and if there are interfaces and transformations of this type, we should obviously be rather careful in using the shape change as indicating a martensitic type of growth. I do not think we can exclude the possibility, but it seems to me very improbable that a shape change would in fact be observed in such a reaction. The reason for this is that if atoms are able to move over large distances during the transformation, the shape change and its associated correspondence could be destroyed completely by a diffusive flow which eliminated lattice sites at one end of the growing crystal and created them at another. The reduction in strain energy obtained by removing the shape change would be an effective driving force for such a flow of atoms, and I cannot see why it should not occur.

It seems likely, then, that a shape change should not be produced for energetic reasons if the individual atoms migrate over large distances during the transformation, and that we are justified in inferring that the interface is martensitic in character when there is a shape change. Where does this leave bainite? Since there is a composition change, there must be long range diffusion of the interstitial carbon atoms, but it seems likely that the ferrite–austenite boundary is martensitic in character because the iron atoms are unable to move many interatomic distances at the temperature of reaction. According to this view, reactions in which the product has a different

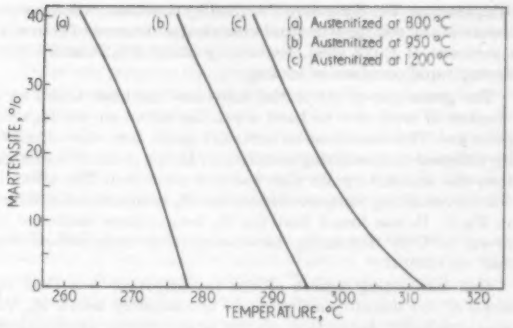


C *Effect of austenitizing temperature on M_s temperature*

composition from the parent can only give a shape change if some of the atoms present can move much less rapidly than others, as happens with an interstitial solution. There should thus be no analogue to the bainitic reaction in purely substitutional alloys; this is borne out by the available evidence for iron alloys, but not by the reported existence of a bainite in copper–zinc alloys.



D *Dependence of slope of transformation curve immediately below M_s on austenitizing temperature*



E *Form of transformation curve obtained with high austenitizing treatment*

Mr **J. A. Venables** (Cambridge University): As the burst phenomenon has come under discussion, what I have to say may be relevant. Figure *B* on p.166 of the previous discussion shows a martensite plate, nucleated in the centre of the grain, which has faulted the next grain beyond the grain boundary B. It seems that if there is a sequential nucleation mechanism $\gamma \rightarrow \epsilon \rightarrow \alpha$, and an α plate produces more faults, or regions which have approximately the ϵ structure, then burst phenomena are likely to occur. If the critical stage in the $\gamma \rightarrow \alpha$ transformation is $\gamma \rightarrow \epsilon$, or the nucleation of faults, $\epsilon \rightarrow \alpha$ being spontaneous, then the α plate will produce faulting which will immediately form more α and a burst will occur. Also in this case there will never be any stable ϵ phase and it will be not observed; as for instance in Fe 20–35%Ni. If the critical stage in the transformation is $\epsilon \rightarrow \alpha$, however, then ϵ will be observed during the transformation and burst phenomena will be less likely, as for instance in the Fe–Mn system and the stainless steel which I have studied.

Mr **M. G. H. Wells*** (Imperial College): I should like to present some results on the effect of austenitizing temperature on the progress of the martensite transformation as a function of

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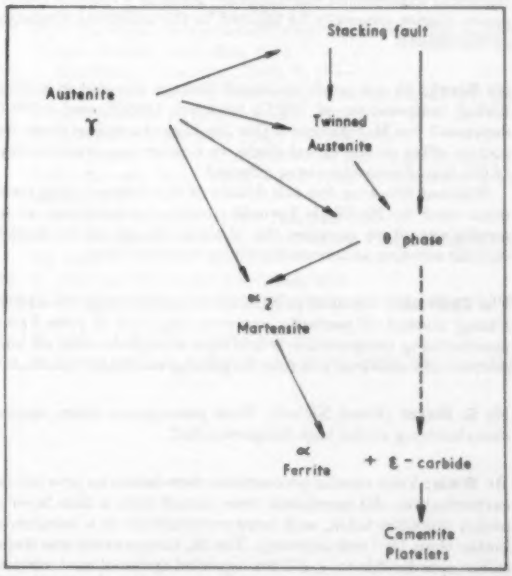

F *Formation of α_2 (martensite) from γ via stacking faults, twin bands, or regions of θ phase*

temperature. The data were obtained by simultaneous measurements of the temperature and electrical resistance of thin wire specimens of En23 steel, containing about 3%Ni and 1%Cr, during rapid continuous cooling.

The grain size of the initial austenite has been found by a number of workers[15] to have a marked effect on the M_s temperature. The variations in austenite grain size were obtained by different austenitizing conditions. In the present investigation the austenite grain size was not measured. The effect of the austenitizing temperature on the M_s temperature is shown in Fig.*C*. It was found that the M_s temperature increased by about 35°C by increasing the austenitizing temperature from 800° to 1200°C.

One interesting aspect of the investigation was that the slope of the transformation curve immediately below M_s was also markedly dependent on the austenitizing temperature. This effect is illustrated in Fig.*D*. It may be seen that at the higher austenitizing temperatures, at say 1200°C, about 1% martensite formed per °C decrease in temperature below M_s, while at the lower austenitizing temperatures, at say 800°C, 3 or 4% martensite formed per °C.

The progress of transformation from M_s to about 40% transformation to martensite for specimens austenitized at 800°, 950°, and 1200°C, respectively, is shown in Fig.*E*. For specimens austenitized at the lower temperatures (that is, less than 850°C), the initial slope of the transformation curve is greatest, and the slope continuously decreases with falling temperature. However, with increasing austenitizing temperature, the maximum slope does not occur at M_s, but some 20°C lower. This effect becomes more marked the higher the austenitizing temperature.

The form of the transformation curve obtained with a high austenitizing treatment (Fig.*E*) is very similar to that obtained by Brook *et al.*[16] who used an austenitizing temperature of 1200°C. However, they reported a small increase in M_s, after a lower temperature austenitizing treatment of 1050°C, in a 4%Cr steel. It is possible that this effect could be due to the incomplete dissolution of stable chromium carbides and the nucleating effect of the consequent carbon depleted regions.

It is not certain whether the effects described above are due to the grain size *per se* or to the thermal history of the specimen. It does appear, however, that the nucleation of the martensite phase is changed by the austenitizing conditions and that the empirical exponential relationship[17] given in Professor Owen's paper cannot generally be applied to the athermal formation of martensite.

Mr **Brook:** In our work we found that an increase in austenitizing temperature of 150°C, between 1050°C and 1200°C, depressed the M_s by about 6°C in the high chromium steels but had no effect on the nickel steels. In neither case was the slope of the transformation curve affected.

Without knowing the full details of the austenitizing treatment used by Mr Wells I would not like to comment on his results except to mention the obvious danger of incomplete carbide solution at low austenitizing temperatures.

The **Chairman:** Another possibility is that you may be austenitizing instead of partially austenitizing, and if your initial austenitizing temperature is not high enough to take all your carbon into solution, you may be getting an effect from that.

Mr **G. Mayer** (Mond Nickel): Were precautions taken against decarburizing at the high temperatures?

Mr **Wells:** Very careful precautions were taken to prevent decarburization. All specimens were plated with a thin layer of nickel 0·0002in thick, and were austenitized in a vacuum of better than 10^{-4} mm mercury. The M_s temperature was found to be reproducible to ± 1°C for repeated cycles of austenitizing and cooling, thereby indicating little or no decarburization.

To minimize the austenitizing time all specimens were rapidly heated to the austenite region from an initial martensite structure at a rate of 100°C/s. This treatment should produce very little carbide formation and hence ensure homogeneous austenite at the austenitizing temperatures used.

Dr **K. W. Andrews** (United Steel Companies Ltd): My first comment is connected with the paper by Owen and Gilbert. The way in which they (and others) have treated the iron–chromium system is interesting because one is left with the feeling that this system is no longer an anomaly as was once thought. Admittedly the treatment involves the assumption of regular solutions but providing certain terms are of similar relatively small magnitudes this effect could occur in other systems. In some other cases therefore one might find a minimum in the γ loop and in others a distortion. This effect would be much more likely the larger the loop since this corresponds to a weaker ferrite forming tendency. Another point arises in connexion with this kind of treatment. It seems to me that if both solid solutions depart from ideality in the same way the ΔFm term as in equation (7) of the paper, will be zero, alternatively equation (9) will apply or $A = B$ in equations (14)–(16). This means that the phase diagram might appear to be based on ideal solution relationships when neither solution is ideal. Again it would appear to be correct to assume that equations (9) and (10) can always be used providing activities are substituted for concentrations. Alternatively, equations (7) and (16) are merely different ways of expressing the same facts except that (16) involves assumptions about the type of interaction between solute and solvent. The validity of this treatment of the system Fe–Cr could presumably be checked by an independent experimental determination of chromium activities.

I have been wondering whether, in the discussion this morning, why we should not also pay attention to martensites formed by plastic deformation as distinct from martensites formed on rapid cooling. For example, Owen and Gilbert give six possible factors which could affect the transformation. Some of these may be relatively unimportant in the formation of martensite during rapid cooling but might become determinative in the transformation induced by plastic deformation. The work of Cina is of much interest in this connexion.[18] He was able to show that a close-packed hexagonal phase (θ) could form in certain iron alloys on quenching and under the influence of deformation. It appeared as an intermediate stage between γ and α_2 (i.e. martensite). It was found in pure Fe–Ni–Cr alloys in considerable amounts but was practically absent from commercial alloys containing carbon. Thus a quenched 18Cr8Ni alloy might contain over 20% of hexagonal θ and this transformed to the body-centred cubic phase on cold deformation more rapidly than the austenite (γ) phase. There was no microscopical evidence of discrete regions of θ. The phase resembled the so-called ϵ-phase of Fe–Mn which also forms under similar conditions.

These observations may be relevant to any discussion of stacking faults in the austenite phase as contributing to the formation of martensite nuclei. Thus we may have the formation of α_2 (martensite) from γ via stacking faults, twin bands, or regions of θ phase (Fig.*F*). Whatever route (direct or indirect) is followed must depend on the relative balance between different factors. To this scheme we must certainly add the early effects of tempering. Thus, orientation relationships which have been postulated show that cementite has a relationship to ϵ-carbide which in its turn has the same arrangement of metal ions as the θ phase and is simply related to the body-centred and face-centred cubic phases.

Professor **J. Nutting** (Leeds University): On the basis of published evidence I had reached essentially the same conclusion as Professor Honeycombe on the effect of carbon upon the stacking fault energy of austenitic steels. However, some recent experimental evidence we have obtained does not seem to support these views. I feel that there is so much we don't know about the factors controlling the stacking fault energy of alloys, that it could be unwise to start making predictions.

Professor **R. W. K. Honeycombe** (Sheffield University): I think there is evidence that this is a reasonable way of thinking. To link the stacking fault energy with the tendency to form ϵ-martensite may not be as direct evidence as thin film observations, but it is a logical deduction to make.

Mr **T. Gladman** (United Steel Companies Ltd): As this discussion deals with the kinetics of martensite formation, it is perhaps relevant to mention the effect of hydrogen on the martensite transformation.

For about three years, we (at Sheffield University) have been studying the effect of hydrogen on this transformation, following the work of Kumar and Quarrell,[19] who showed that hydrogen could produce profound effects on the martensite transformation of certain steels. In particular, hydrogen markedly depressed the later stages of martensite transformation to lower temperatures in a 0·3%C–4%Ni–Cr–Mo steel, and depressed the M_s temperature by about 50°C in a 0·6%C–3%Cr–Mo steel.

The results obtained on repeating this work were rather disappointing, for, in fact, we did not find any effect of hydrogen *per se*, on either the martensite or the bainite transformation. Further work showed that the effect noted in the 0·3%C–4%Ni–Cr–Mo steel could be attributed to a faulty technique, but despite the fact that the experiments on the 0·6%C–3%Cr–Mo steel were repeated on several casts to the same nominal composition, no depression of M_s was observed.

In view of our experience, it would be interesting to hear of any other results obtained on this topic.

Mr **C. H. White** (Sheffield University): Professor Honeycombe and Dr Andrews have mentioned Hadfields' manganese type of steel. We have been studying iron–manganese and iron–manganese–carbon systems, using the electron microscope and X-ray techniques.

We started with the Hadfields' manganese steel. Previous theories had suggested that it is due to a martensite transformation which gives a work-hardening effect. During our examination we used impact deformation and slow compression, at temperatures up to 400°C and down to −196°C. At no stage was martensite ever found. However, if the carbon is reduced, you get the martensite transformation at room temperature with a carbon content of 0·4%. At −196°C the straight quenching does not produce anything except at a carbon content of 0·4%, but if you deform after quenching you get martensite transformations formed at a carbon content of 0·8%. An interesting feature of this transformation is that two types of martensite are involved. One is the normal body-centred type. The other is the hexagonal type. This is only in very small quantities, possibly something like 5%; certainly no more than that.

With alloys up to 8%Mg but containing no carbon you get a body-centred cubic phase. At a content of 13–18% you get epsilon and body-centred cubic phase, and also some retained austenite.

There is an interesting point in connexion with the 18% manganese alloy, where the epsilon is the major phase. With increasing deformation you get decreasing amounts of α, whereas the epsilon remains practically constant. With a 25% alloy content, you have only epsilon and gamma, and there is no alpha at all.

Varying the manganese content instead of the carbon content has very little effect. The alloys remain practically completely austenitic, except for the 4% manganese alloy where at room temperature you get very few needles of a normal tetragonal phase.

There still remains the problem of what gives you the work hardening of austenitic manganese steel. I have shown that the formation of martensite has no place in the theory. We believe that is it bound up with the formation of stacking faults. Nishiama, in Japan, has presented some results showing parallel plates of the epsilon produced on the 111 planes of austenite and stacking faults upset the plate holes involved.

Dr **D. Hull** (Liverpool University): It is established that the interfaces of the massive transformation consist of a large number of short straight sections. They seem crystallographic but are fairly irregular in that the short lengths do not appear to follow any particular direction. I wonder whether the model proposed by Dr Christian accounts for these irregular interfaces, in that one particle of massive alpha has a number of interfacial facets.

Dr **Christian:** I do not know.

Dr **B. A. Bilby** (Sheffield University): I mentioned that we were misquoted, and this caused Professor Owen to return to the shape change as the fundamental thing in the deformation. I am now inclined to think that really the diffusionless character is best regarded as the important one. I think that Dr Christian put his finger on the point in speaking of the labelled atoms. What we tried to say was that we would call it martensite if there was some lattice of points in the one phase which went to the same lattice in the other one. But this does not imply that there is an overall shape change. In fact, I showed in the slide an example with a zero shape change.

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Session 3

At session 3 the following papers were presented and discussed:

'Effect of composition on the structure and properties of martensite', by *K. J. Irvine, F. B. Pickering*, both of United Steel Companies Ltd, and *J Garstone*, Quasi Arc Ltd (*JISI*, 1960, **196**, Sept., 66–81)

'The mechanical properties of some tempered alloy martensites', by *J. M. Capus*, Gillette Research Laboratories, and *G. Mayer*, International Nickel Co. (Mond) Ltd (*JISI*, 1960, **196**, Oct., 149–158)

'The toughness of tempered martensite', by *D. Hardwick* and *K. R. Pirt*, Brown-Firth Research Laboratories (*JISI*, 1960, **196**, Nov., 301–308).

Dr **N. P. Allen**, F.R.S. (National Physical Laboratory): My interest in the properties of tempered martensite stems from the time when I was working on pearlitic, bainitic, and martensitic transformations in alloy steels and wanted to know whether in hardening steels it was necessary to suppress the pearlitic transformation alone or both the pearlitic and bainitic transformations. It turned out that for the best properties both should be suppressed, but the principal difference was that at equal tensile strength the impact values of tempered martensite were higher than those of tempered bainite.

The question then arose whether the higher impact values of tempered martensite were of practical use. At that time there was no very clear answer. The chief change which has taken place during the intervening 20 years has been a growing realization of the significance of the impact transition temperature, and as a result a great deal of work has been reported, and the relations between the impact transition temperature and the heat treatment have become clearer.

At about the time when I was working on this subject, hardenability tests became fashionable. The claim was widely made that if one knew the hardness of a quenched and tempered steel one knew all its mechanical properties; and was fairly convincingly established in respect of tensile strength, yield point, elongation, and reduction of area, but broke down completely in respect of impact values and impact transition temperatures. It has since come to be recognized that the variations of impact properties occurring in steels of like hardness are somehow wrapped up with the fineness and uniformity of the structure and the purity of the material, but it is still impossible to say what is the value of a change of notched-bar transition temperature in terms of the stress that can safely be applied to the structure. I think that the time is now ripe for finding out.

We see that for a quenched and tempered alloy steel, according to the nature of the as-quenched structure, the relationship between the transition temperature and the tensile strength is expressed by a series of rather complex curves, and it is possible to have steels both of equal tensile strength and different transition temperature and of equal transition temperature and differing tensile strength. We ought to be able to say under what mechanical conditions it is possible to use steels of each kind; but it cannot by any means be said that we can do this, and I am coming to the belief that our ignorance is largely because we have concentrated attention on the energy absorbed and have not given enough attention to the actual stress at which the fracture occurs. Indeed, in these papers there is a noticeable tendency to forget even the energy and report only the transition temperature of the steel. This policy was commendable so long as we were sorting out the conditions which affect the behaviour of the material; but we are beginning to know something about the variables now, and it is time to consider the value of the low and high impact transition temperatures in terms of the mechanical duty one can expect of the steel.

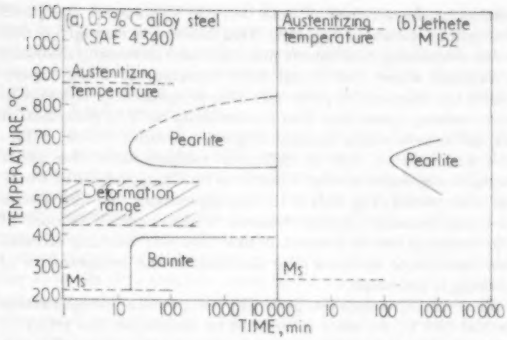
However, I have one reservation to make to that general conclusion, and would refer to the earlier paper by Cina and Jubb,[1] of which the Hardwick and Pirt paper is a continuation. Cina and Jubb studied the variation of impact transition temperature in one kind of alloy steel and found it to be something over 200°C. An analysis of their figures shows that variations in the tensile strength can account for about 100°C. Variations of heat treatment, which of course are not unconnected with the variations of tensile strength, can account for about 180°C. It is very interesting to notice that in our work at the National Physical Laboratory it was found that a similar variation was produced by heat-treatment in a pure iron–carbon alloy containing 0·05%C. Variations of grain size, to which the same remark can be applied, can account for about 100°C and the phenomenon of temper brittleness seems to be capable of accounting for about 60° or 70°C. The most interesting aspect of Cina and Jubb's paper, particularly that part of it which dealt with the impact transition temperatures of large rotor forgings, was that when the variations of all the controlled factors had been taken into account there were still variations of about 90°C in the impact transition temperatures of nominally similar steels, for which no explanation was available. Metallographers ought to be concerned about that, for there is obviously something that is not understood.

In this connexion the paper by Capus and Mayer on the influence of impurities is very welcome. They found that if one purified the steel one got a significant increase of impact value in certain ranges of hardness, but one does not know what use to make of that improvement. In their further work they were trying to find out what that use could be. They looked for improved notch fatigue strength at high levels of loading, but I cannot help remembering that when I tried to find a connexion between the notched-bar transition temperature of a steel and its notched fatigue limit I found no relation. However, they are looking for a relation at high levels of stress and low endurance; and this is possibly sound because there cannot be very much difference between the effect of applying a load to a piece of steel once, and applying it two or three times. There must be some connexion between single blows and high stress fatigue tests, and the nature of that connexion ought to be established.

The paper by Irvine *et al.* prompts me to indulge in a slight grumble. They did not tell us very much about their materials or microscopic techniques, and on that account I found it extremely difficult to criticize the paper. This is no doubt due to the continual demand for condensation of papers which the Publications Committee makes of us, but we should not condense papers to such an extent that the essential experimental details are omitted and the work cannot be properly evaluated.

I gathered that the electron micrographs in the paper were taken with the aid of replicas, and these often suffer a good deal in reproduction; but I did not quite see the justification for the importance attached to the strings of carbide precipitates between the martensite needles which seem to me to be present most of the time. I was also inclined to quarrel with the importance attached to grain size as compared to the effect of the precipitated carbide. From the pictures I could not see what the grain size of the samples actually was, and from what has passed this morning about the structure of the martensite needle I feel that no-one else could tell from the pictures either.

The most interesting aspect of the paper is Table I, which refers to the mechanical properties of plain carbon steels. Whenever the authors encounter a specimen which breaks before it yields they dismiss the result as premature fracture, as if there were something wrong with the test. Upon examination one finds a perfectly good set of results, showing quite systematic variation of the breaking stress. For equal tempering treatment the breaking stress goes down with increasing carbon content, and for equal carbon content it rises pretty systematically as tempering proceeds. These breaking stresses thus represent, I think, a real mechanical characteristic of the material, and one should not ignore them. There is no very obvious connexion between the breaking stress displayed and the impact value in ft/lb, nor is there a direct association with hardness. The 0·7%C steels show premature fractures when the hardness is as low as 516 DPN, whereas the 0·3%C steels show



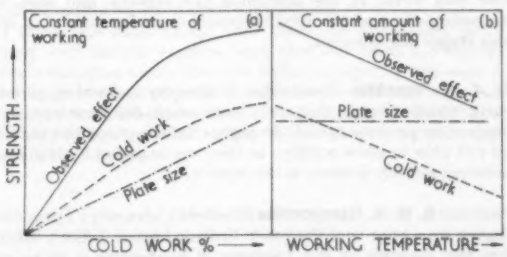
A *TTT diagrams for a 0·5%C alloy steel (SAE 4340) and Jethete M 152*

freedom from premature fracture with hardnesses as high as 600. If we knew what was the cause of this difference and of the change in susceptibility to early fracture that occurred between 200° and 300°C in a 0·5%C steel and at some temperature above 300°C in a 0·7%C steel, I think we should be going a long way towards understanding how to make a high tensile steel with sufficient ductility to be useful. From this point of view the study of the stresses under which martensite breaks is a neglected subject to which we ought to give more attention.

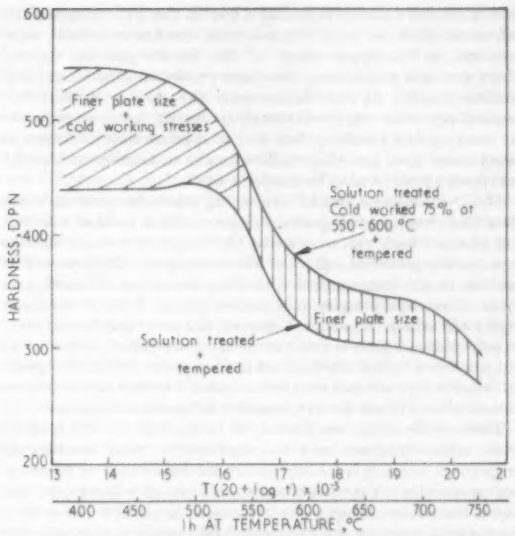
Professor **J. Nutting** (Leeds University): Dr Irvine and Mr Pickering conclude that 'The major factor controlling the hardness of martensite is the amount of carbon in solid solution'. Dr Kelly and I have discussed this in a recent paper.[3] We find it difficult to believe that carbon in solid solution can bring about such a large change in hardness, and we have proposed that the influence of carbon is to change the M_s temperature. When the carbon content is low the M_s temperature is high and the transformation products are the relatively soft needle-shaped grains. When the carbon content is high the M_s temperature is low and the transformation products are plate-like grains containing fine twins. The twin boundaries act as barriers to dislocation movement, hence the plate-like grains are relatively hard.

Superimposed upon the change of hardness induced by the change of microstructure, there is the change brought about by the increase in the amount of carbon in solid solution. But it now seems that this is not the major effect.

Dr **Irvine:** I am interested in the suggestion put forward by Professor Nutting. In our paper it was concluded that solid solution hardening was the most important factor contributing to the hardness of martensite. This was mainly because it was shown that the variation in grain size was very small and there were no other structural features which could be observed using replica methods for electron microscope examination. Nutting and Kelly, however, have now developed the thin film technique, which does show some structural changes which



B *Schematic illustrations on the effects present after austenitic cold working*


Finer plate size + cold working stresses
Solution treated Cold worked 75% at 550 - 600 °C + tempered
Finer plate size
Solution treated + tempered
HARDNESS, DPN
T (20 + log t) x 10⁻³
1h AT TEMPERATURE, °C

C *Schematic illustration of effects present during the tempering of solution-treated and austenitic cold-worked materials, Jethete M152, cast S87*

must be influencing the properties of martensite, particularly at higher carbon contents. The effect of solid solution hardening cannot be dismissed as it is undoubtedly the major effect in low carbon martensites and it must be remembered that it is low carbon steels which are of more interest commercially.

One exception to this general statement is that high-carbon, lightly-tempered martensites are used where the most important property is wear resistance, such as in a bearing steel. In this case, there is considerable interest in the fracture characteristics since the usual failure is pitting fatigue. If in fact there is a major change in the structure of the high-carbon martensites, as Professor Nutting is indicating in his work, then it seems likely that the fracture characteristics will also vary and this could be a fruitful field of study.

Professor Nutting took the lead in the application of carbon replica techniques for the electron microscope studies of ferrous structures. He is to be congratulated for doing the same now with thin film techniques. Our laboratory has benefitted very much from close contact with him in the past, and we now consider that these thin film techniques should help us very much in the future, particularly for the study of martensitic structures.

Professor **Robert F. Mehl** (Carnegie Institute of Technology; US Steel Corporation): I thought it might interest you to hear about the recent work done in the United States on the effect of prior deformation on the properties of quenched steel. The work really began with a short note by Lips and van Zuilen in *Metal Progress* in 1954. These authors, however, gave but little information on either the techniques employed or the results obtained. Substantial research on this subject was undertaken by Zackay and his associates at the Ford Company research laboratories in Detroit (*ASM Preprint no.*110, 1958; *ibid.*, no.163, 1959). Zackay chose steels, e.g. chromium steels, which exhibit a bay in the TTT curve, i.e. a temperature region of very slow reaction; such steels were worked in this temperature region, up to 75% reduction in thickness by rolling, and then quenched. Yield strengths as high as nearly 200 tons/in² were observed, with the accompanying ductility quite good. Zackay produced much systematic data.

Grange at the Fundamental Research Laboratory of the US Steel Corporation at Monroeville, near Pittsburgh, (private communication, to be published shortly), attacked the problem in a different way: instead of deforming in a bay region and

thus requiring a steel exhibiting a bay in the TTT diagram, he deformed steels at temperatures near the lower critical temperature, in the upper range of the ferrite–pearlite region, where reaction rate is very slow, and produced somewhat comparable results. In this latter case the danger is that the worked austenite might recrystallize during the time required for working and handling, but it now appears that austenite in many cases does not recrystallize nearly so rapidly as feared,[3] and the treatment may be made to work.

The work raises a host of interesting scientific questions: it is clear that working the grains elongates them, so that martensite plates which run normal to the length are much shorter than in the previous equiaxed austenite grain. Thus tested in tension in the longitudinal direction, the plane of maximum shear 'sees' many more martensite plates, with a resultant high yield stress. Whether, however, the total number of martensite plates is less is not yet firmly established; nor is it as yet known whether surfaces of deformation within the grain are wholly free of reaction product, and whether such surfaces in themselves block the propagation of martensite plates.

There is of course much more to be done in this field, apart from microstructure and its correlation with mechanical properties; nothing is known about the anisotropy of mechanical properties (of course there should be an anisotropy), the notch toughness, fatigue, etc. The work must now proceed to steel sections larger than the small laboratory specimens this far employed. But the practical promise is great, and the matter is fully worth further extensive exploration.

Dr **P. M. Kelly** (Leeds University): The 'basic' hardness of martensite is the summation of three effects, which are virtually independent of the carbon content. These three factors are: (*a*) the hardness of ferrite, (*b*) the hardness due to the small grain size, (*c*) the deformation accompanying the transformation. Thus, the hardness of a hypothetical, carbon-free martensite should be merely that of fine-grained, cold-worked ferrite.

The addition of carbon affects the hardness in two ways. The first of these is the effect of carbon in solution, which is of a two-fold nature. At low values of carbon content the dislocations produced during the transformation will be locked by carbon, thus giving an increase in hardness. Once the dislocations are saturated with carbon, any further increase in carbon content will only harden the steel by introducing internal strain and the rate of increase of hardness with carbon content will fall. The second factor contributing to the variation of hardness with carbon content is the relative amount of internally twinned martensite present and this varies sigmoidally from 0% at zero carbon to 100% at 0·8 to 1% carbon.

If dissolved carbon alone was responsible for the variation in hardness of martensite, a 1·7%C steel should have a hardness of over 1500 DPN. Microhardness measurements on 1·7% carbon martensite[4] have shown that the hardness is just under 1000 DPN, and this supports the suggestion that internal twinning also contributes to the hardness of martensite. More work on low-C alloy steels, which transform to internally twinned martensite, is necessary before the relative importance of these two factors can be evaluated.

Mr **D. T. Llewellyn** (United Steel Companies Ltd): After the paper by Irvine *et al.* was submitted for publication, further work on austenite-forming was carried out which has shown up interesting features in this process. Experiments were carried out on a 12%Cr steel because this type of composition has a very simple TTT diagram compared with the 0·5%C steel which was used by workers at the Ford Scientific Laboratory. This is illustrated in Fig.*A* which shows that the 0·5%C steel allows only a limited temperature range for working, whereas the 12%Cr steel can be worked at any temperature between M_s and temperatures which would cause recrystallization.

On cooling from the austenitizing temperature and 'cold working' at temperatures between 900° and 500°C the results that have been obtained are shown schematically in Fig.*B*. If the temperature of working is kept constant the effect of increasing the amount of cold work is to increase the proof strength as shown in Fig.*B*(*a*). This increase in strength is due to the decreasing martensite plate size and increasing amounts of internal stress that result from working. In these experiments the martensite plate size was progressively reduced in cold working operations that produced up to 75% reduction of original cross-section in area. If given amounts of cold reduction are carried out at different temperatures the proof strength decreases almost linearly as the temperature of working is increased (Fig.*B*(*b*)). In this experiment the martensite plate size remains constant because of the constant amount of cold working but it is obvious that the cold-working stresses that contribute to hardening decrease as the temperature of working is increased.

Since 12%Cr steels are generally tempered at temperatures around 650°C, we were interested to determine the effect of tempering on austenite-formed materials. The type of result that has been obtained is shown in Fig.*C*. In the untempered condition austenite-forming produces a big increase in hardness compared with the solution-treated condition and this advantage in hardness is maintained after tempering at temperatures up to about 550°C. Tempering at higher temperatures reduces the difference in hardness between austenite-formed and solution-treated condition. This effect is thought to be due to the relief of cold-working stresses as the temperature of tempering is increased above 550°C. An electron microscopical examination has revealed that the tempering process is similar in both the solution-treated and austenite-formed conditions. After tempering at 650°C, both materials show a very similar distribution of $M_{23}C_6$ and M_2X precipitates and in this condition the only difference in microstructure is the very much finer plate size of the austenite-formed material.

It is obvious therefore that when considering the results produced by austenite-forming, it is necessary to take into account both the residual stress and the finer martensite plate size aspects and in work so far published little or no consideration has been given to the contribution of work hardening.

Professor **W. S. Owen** (Liverpool University): I understand that one can also get very large increases in strength in these sorts of steels by transforming the austenite under very high hydrostatic pressures. The main feature of this mode of transformation is that it also lowers the M_s quite appreciably. This would fit in with what Dr Kelly said.

Professor **Mehl**: It is curious that the M_s point should be lowered. I have not my diagrams with me, but as I recall it, for a steel showing a secondary hardness on tempering, plotting yield stress (as I think you call proof stress) for a 60 or 75% austenite-formed steel, the tensile and the yield are pretty much the same, and very much higher, so that a curve of that sort is obtained at the maximum strength. That is not the same as the position with 12%Cr steel. The benefit is retained, indeed exaggerated.

Dr **B. A. Bilby** (Sheffield University): Professor Mehl says that it is curious that the M_s should be lowered by deformation; but is it if one accepts that the control of M_s is essentially athermal? One would accept the growth process to be more difficult after cold work. In the beginning one expects, and sees, a nucleation effect which would promote transformation but at later stages one does not.

Mr **J. A. Venables** (Cambridge University): Another point worth mentioning is that only very small deformations are required to produce nuclei. At higher deformations the nuclei are not able to grow readily, as they are impeded by the dislocations already present in the matrix.

Professor **R. W. K. Honeycombe** (Sheffield University): I propose digging up a bone that Professor Nutting buried. I don't think that the question of the hardness of martensite is quite as straightforward as Professor Nutting made out. I agree that this thin film work, which has revealed fine twins in the needles,

has been a major development in our understanding of martensite, but I do not believe one can brush away the effect of carbon in solid solution as being zero. I think one has to take into account not only the structural aspects which Professor Nutting has pointed out, but also the solid solution effect which is, I feel, considerable.

Even in the absence of martensite, one can get a three or four-fold increase in the yield strength of ferrite by the addition of small concentrations of carbon. On quenching to form martensite, the concentration of carbon in solution can be greatly increased, and the accompanying lattice distortion must lead to a substantial increase in yield stress. In a number of other systems with interstitial solutes, there is a considerable increase in hardness, even when no martensitic transformation takes place. It cannot be denied that these fine twins must contribute to the hardness, but it is far from clear what their contribution will be, and whether it will be any greater than that due to solution hardening.

Dr **Kelly:** I should like to comment on what Professor Mehl has said about the austenite-forming process and the explanation of the increase in strength in terms of a reduction in grain size. It is possible that warm-working the steel in the austenitic state has another effect on the subsequent transformation.

Previous work[6–11] has shown that heavy deformation of austenite at temperatures above the M_s leads to a depression in the M_s temperature and a reduction in the amount of martensite formed when the steel is quenched. Thus, austenite-forming should result in a lowering of the temperature range over which the martensite transformation occurs. This lowering of the transformation temperature range should increase the tendency for internally twinned martensite to form in preference to needles. As Professor Nutting remarked earlier, we believe that internal twinning is an important factor in the hardness of martensite.[12] Thus, if austenite-forming increases the amount of internally twinned martensite formed on quenching, the hardness will be increased and this effect combined with the small grain size should account for the observed increase in strength.

Mr **W. E. Duckworth** (BISRA): We have been doing some work on the influence of cross slip on fatigue failure. It is known that cross slip must play a part. I am wondering if someone would care to express his views on the relative ease of cross slip formation under fatigue stresses in the various kinds of martensite which we have been discussing.

Professor **Nutting:** Cross slip could occur in the needle form of martensite, but it would be difficult, because as a result of the phase transformation the dislocation content of the needles is high, i.e. they are already work-hardened. It would appear to be very difficult to get dislocation movement under any circumstances in twinned martensite plates.

Dr **Irvine:** Dr Allen's criticism of our mode of presentation is an example of the continual argument between referee and author concerning what is to be included in a paper and what is to be left out. My own opinion is that papers do not gain from the insertion of large tables. A large number of steels were examined and I do not think it would have been any use at all including tables of their composition.

I think one must accept that there are established techniques with carbon replicas, and that one need not repeat those techniques every time one writes a paper. There were a very large number of grain size measurements and samples. It seemed to us that the statement that the grain size did not vary said as much as could many tables. Brevity occasionally helps in this matter.

Dr **Hardwick:** I should like to refer briefly to the remarks made by Dr Allen on the use to be made of transition temperatures. In our paper the aim was a fuller understanding of the factors affecting transition temperature, divorced from any practical considerations. It is important, however, to know whether a transition temperature as determined on small specimens has any relationship with required service properties.

Let us consider for a moment the problem of large alternator rotor forgings. It is our aim to reduce the transition temperature of such components to as low a level as possible. It has been shown that if discs cut from such forgings are notched and spun to destruction, the bursting stress varies with composition and heat treatment. Further, the bursting stress may be considerably lower than the true fracture stress in a tensile test. It is this difference between bursting stress and fracture stress that worries the design engineer. It can be shown that there is some relationship between the bursting stress of discs and the transition temperature as determined on small Charpy specimens, the disc with the lowest bursting stress having the highest transition temperature and vice versa. There is a real practical reason, therefore, for transition temperature determination on these materials and hence some justification for the research effort involved.

I would point out, however, that neither the transition temperature nor the energy values from the transition curves help the engineer to decide whether a material is going to fail at any particular stress. What he wants is some quantitative figure which can be used in his design. Newhouse and Wundt[13] claim that such information can be obtained from a modification of the standard Charpy test. By nitriding the machined specimen, a brittle boundary is formed and it is claimed that this allows separation of the energy required for crack initiation from that required for propagation. The energy values obtained from specimens exhibiting the first sign of ductile fracture, when suitably converted, are claimed to allow calculation of fracture toughness, a property which can be directly used in design.

However, one or two experiments carried out in the Brown-Firth Research Laboratories indicate that when using this method on steels of different analysis, the difference in nitriding behaviour may introduce some uncertainty into the comparison.

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Co-operation with sister institutions

ADDENDUM TO THE REPORT OF COUNCIL FOR 1960

The following statement, copies of which have been circulated to Members, forms an Addendum to the Report of Council for 1960 which will be published in the July issue of the Journal.

Co-operation with The Institute of Metals and The Institution of Metallurgists

Prolonged discussions during 1960 have resulted in complete agreement between the Councils of The Iron and Steel Institute, The Institute of Metals, and The Institution of Metallurgists on the best way to assure that the three societies work more closely together, avoid overlapping and duplication in their activities, and provide improved service for Members.

A Joint Consultative Committee has been set up. This will keep under review all matters of common interest and advise the Councils on appropriate action.

The three Councils are convinced that it is in the interests of the profession and of their members that qualified metallurgists shall be members both of the professional Institution and of the appropriate scientific and technical Institute. Accordingly, it has been agreed that, as from 1 January 1962, there shall be joint subscriptions to cover membership of the Institution and of one or both Institutes. The agreed rates are set out below. They will apply, subject to election by the Institutes, to all members of the Institution resident in the UK and optionally to members of the Institution resident overseas.

The Councils of The Iron and Steel Institute and The Institute of Metals recognize that this decision is likely to result in a considerable increase in the membership of the two Institutes. The Council of The Iron and Steel Institute welcome this and hope that the service which the Institute provides will be satisfactory to new as well as to old Members. It is their constant endeavour to improve this service. At the same time, they think it is appropriate to point out that agreed subscription rates will involve the Institute in some financial sacrifice owing to the high cost of servicing Members. Nevertheless, they are firmly convinced that the agreed policy is right and in the best interests of the membership of The Iron and Steel Institute as a whole as well as of metallurgists. The proposals provide for joint subscriptions roughly comparable to those payable by members of other Institutions which provide similar service and also include reduced rates for those who are younger and in the lower grades of membership of the Institution.

The three Councils have agreed that, as from 1 January 1962, the subscription payable by each member of The Institution of Metallurgists resident in the United Kingdom (and optionally by members resident outside the United Kingdom) shall include also the subscription payable to either The Iron and Steel Institute or The Institute of Metals or to both Institutes. The rates are as shown in the table (as covered by by-law 21 of The Iron and Steel Institute).

There will be no change in the subscriptions payable to The Iron and Steel Institute by Members who are not members of The Institution of Metallurgists. These rates remain as follows:

	Standard rate, per annum	Reduced rate,* per annum
	£ s d	£ s d
Ordinary members	5 5 0	4 14 6
Associate members		
aged 25–27	3 3 0	2 12 6
aged 24 or less	1 15 0	1 11 0

* Payable by those who are also members of The Institute of Metals or of an Affiliated Local Society or of a Kindred Society overseas.

New Members elected at the Annual General Meeting in any year will be required to pay the appropriate subscription for the year of election. Members elected at the Autumn General Meeting in any year will be required to pay half of the annual rate if the application for membership is received before 31 October and no subscription for that year if the application for membership is received on or after 1 November. In accordance with present practice, the monthly *Journal* and notices of meetings will be sent to all applicants for membership pending election.

Members of The Iron and Steel Institute who are also members of The Institution of Metallurgists will receive from the Secretary of the Institute and from the Registrar-Secretary of the Institution formal notification of their new total rate of annual subscription and, if appropriate, an amended Banker's Order form. Until this no action is needed. In most cases the new subscription will be somewhat less than that now payable. Members who are assessable to United Kingdom Income Tax under Schedule E are reminded that they can claim relief of tax in respect of their subscriptions.

The Council hope that those who are at present members of the Institute and of the Institution will continue their Joint Membership, and that those Members of the Institute who are qualified but have not so far joined the Institution will do so.

Rates of subscription

Grade of membership in The Institution of Metallurgists	Grade of membership in The Iron and Steel Institute	Annual subscription payable by an individual who is: A member of The Iron and Steel Institute and of The Institution of Metallurgists — Present rate	Rate as from 1.1.62	A member of The Iron and Steel Institute and of The Institute of Metals and of The Institution of Metallurgists — Present rate	Rate as from 1.1.62
		£ s d	£ s d	£ s d	£ s d
Fellows	Ordinary member	9 9 0	9 10 0	14 3 6	14 0 0
Associates*					
28 or more	Ordinary member	7 7 0	6 10 0	12 1 6	9 15 0
25–27	Associate member	5 5 0	5 0 0	7 17 6	7 15 0
Licentiates*					
28 or more	Ordinary member	5 19 6	5 0 0	10 14 0	8 0 0
25–27	Associate member	3 17 6	4 0 0	6 10 0	6 10 0
24 or less	Associate member	2 16 0	2 10 0	4 7 0	4 0 0
Graduates*					
28 or more	Ordinary member	5 14 6	3 15 0	10 9 0	6 0 0
25–27	Associate member	3 12 6	3 0 0	6 5 0	5 0 0
24 or less	Associate member	2 11 6	2 10 0	4 2 6	4 0 0
Students*					
28 or more	Ordinary member	5 9 6	3 15 0	10 4 0	6 0 0
25–27	Associate member	3 7 6	3 0 0	6 0 0	5 0 0
24 or less	Associate member	2 6 0	2 0 0	3 17 0	3 5 0

* Age as at 1 January in the subscription year in question.

NEWS | *Announcements and News of Science and Industry*

THE IRON AND STEEL INSTITUTE

Special meeting in USA and Canada October–November 1961

The provisional programme of the Special Meeting of the Institute in the USA and Canada this autumn was given on p.83 of the May issue of the *Journal*.

There will be an official welcome in New York City on **Thursday, 19 October,** but it is anticipated that some members will arrive a day or two earlier.

Members will be able to travel to and from the USA by normal sea and air routes, but in addition a Britannia aircraft will be chartered for Atlantic crossings at substantially reduced cost. Provisional dates for these crossings are: to New York, **Tuesday, 17 October;** from New York, **Wednesday, 8 November 1961.**

Preliminary estimates of cost are included in the programme recently circulated to members.

Autumn General Meeting 1961

The Institute's Autumn General Meeting will be held in London on **Wednesday and Thursday, 29 and 30 November 1961.** The main technical sessions will be devoted to a symposium on 'The future of ironmaking'. Full details will be published later in the *Journal*

NEWS OF MEMBERS

Mr **W. Ash** has been appointed deputy chief metallurgist at Steel, Peech and Tozer.

Mr **E. A. Atkin,** formerly assistant chief engineer, has been appointed deputy chief engineer of Appleby-Frodingham Steel Company.

Mr **G. R. Buckley** has been elected a director of Staveley Iron and Chemical Co.

Mr **D. P. W. Campbell** has been appointed process development officer at the Redbourn works of Richard Thomas and Baldwins Ltd.

Mr **J. Clark** is now chief inspection engineer with the central engineering and plant construction department of Dorman Long (Steel) Ltd.

Mr **J. D. Dickerson** is now assistant manager of the Foreign Management Department, Koppers Company Inc., Pittsburgh, Pa., USA.

Mr **A. Drijver** has been elected to the board of managing directors of Breedband NV, and Koninklijke Nederlandsche Hoogovens en Stalfabrieken NV, IJmuiden, Holland.

Dr **U. R. Evans,** F.R.S., has been awarded the honorary degree of Doctor of Metallurgy by the University of Sheffield.

Dr **Edwin Gregory** has relinquished his full-time executive position as chief metallurgist, but will remain as non-executive director, of Edgar Allen and Co. Ltd.

Mr **G. H. Hayter** has been appointed works manager of the Ickles departments and bar mills of Steel, Peech and Tozer.

Mr **L. D. Hewitt** is now with the department of research and technical development at Stewarts and Lloyds Ltd, Corby.

Mr **H. W. G. Hignett** has been appointed a director of The International Nickel Company (Mond) Ltd.

Mr **A. G. Hock** has been appointed metallurgical consultant of the Workington Iron and Steel Company.

Mr **R. S. Howes** has been appointed works manager of the steelmaking and primary mills of Steel, Peech and Tozer.

Dr **B. B. Hundy** has been appointed chief metallurgist at Steel, Peech and Tozer

Mr **E. T. Judge** (*Vice-President*) has been appointed deputy chairman of Dorman, Long and Co. Ltd, and managing director of Dorman Long (Steel) Ltd, following the retirement of Sir Ellis Hunter, G.B.E.

Dr **H. K. M. Lloyd** has been appointed to the chair of metallurgy at University College of South Wales and Monmouthshire, Cardiff, in succession to Professor W. R. D. Jones, with effect from 1 September 1961.

Mr **G. E. Lunt** has been appointed a director of John Hill and Sons (Iron Founders) Ltd, a member company of Staveley Industries Ltd.

Dr **T. U. Matthew** has been appointed director of manufacturing with Massey-Ferguson (United Kingdom) Ltd, Coventry. He has relinquished all his directorships and other appointments in the Tube Investments Group.

Mr **E. L. Morgan** has been appointed chief metallurgist of the Workington Iron and Steel Company.

Mr **R. F. J. Morgan** has joined the research and development department of Davy and United Engineering Company Ltd.

Mr **K. A. Oliver** is now chief metallurgist of The Brightside Foundry and Engineering Co. Ltd.

Mr **A. H. Pople** is now deputy combustion engineer at the Ebbw Vale Works of Richard Thomas and Baldwins.

Mr **A. Sandelands** is now an assistant lecturer at the Workington College of Further Education.

Mr **G. Schjelderup** (*Hon. Vice-President*) has retired from the post of President of Christiania Spigerverk, Oslo, but remains as Chairman and in a consultant capacity.

Professor **C. S. Smith,** formerly professor of metallurgy at the University of Chicago, has been appointed institute professor of the Massachusetts Institute of Technology.

Mr **J. Ivan Spens,** O.B.E., has been appointed president of the London Tin Corporation.

Mr **F. W. E. Spies** has been appointed chairman of the board of assistant managing directors of Breedband NV, and Koninklijke Nederlandsche Hoogovens en Stalfabrieken NV, IJmuiden, Holland.

Mr **E. M. Summers** has been elected a director of the Staveley Iron and Chemical Co.

Mr **A. F. Sutton** is now development engineer with Plibrico Ltd.

Mr **R. F. A. Turner** has been elected a director of the Staveley Iron and Chemical Co.

Mr **J. M. Willey** is now managing director of Murex Welding Processes Ltd.

Obituary

Henry Richard Ayton (*elected* 1936), of Torquay, on 13 February 1961.

E. Homer Kendall (*elected* 1959), of Alliance, Ohio, USA, on 5 April 1961.

William Leonard Knoyle (*elected* 1920), of Penllergaer, Swansea, in May 1960.

John Henry Pickton (*elected* 1953), of Penketh, near Warrington, in 1961.

Thomas Reynolds (*elected* 1951), of Birmingham, on 1 November 1960.

C. H. Roden (*elected* 1946), of Corby, on 25 November 1960.

Maurice de Wendel (*elected* 1909), of Joeuf (Meurthe-et-Moselle), France, on 19 March 1961.

Urias Williams (*elected* 1923), of Briton Ferry, in 1960.

AFFILIATED LOCAL SOCIETIES

West of England Metallurgical Society

At a meeting of the Council of The Iron and Steel Institute on 16 March it was unanimously agreed that the West of England Metallurgical Society should become affiliated to The Iron and Steel Institute. Officers of the Society are:

President G. H. Moore (Principal of the College of Technology, Bristol)
Chairman E. R. Gadd (assistant chief engineer (metallurgy) Bristol Siddeley Engines)
Vice-Chairman B. Walters (National Smelting Company)
Secretary P. Thornton (Lecturer in metallurgy, College of Technology, Bristol)
Treasurer W. H. Dearden (lecturer in metallurgy, The University, Bristol)
Members of the Committee K. R. Wilson, T. Murphy, G. R. Pitts, A. Smith, Dr A. T. Churchman, W. J. Bayley, C. F. Harris.

Mr Moore is *ex-officio* an Honorary Member of the Council of The Iron and Steel Institute during his period of office.

The Society meets at the College of Technology, Bristol, and last season it arranged a number of highly successful lectures on topics including factors concerned in the failure of metals, slag functions in non-ferrous metallurgy, recent developments in metallography, metallurgy in modern jewellery, physical methods of analysis, and temperature measurement.

The Society has over 100 members. Subscription is £1 1*s.* for full members and 5*s.* for associates. Further details of the Society's activities are available from the honorary secretary, Mr Philip Thornton, Metallurgy Section, College of Technology, Ashley Down Bristol 7.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Sheffield Open Days

The last open days held at the Sheffield laboratories of BISRA, which deal with research and development in steelmaking, mechanical working, and metallurgy, were in 1956. Many developments that have taken place during the last four years will be on exhibition on 15 and 16 June.

The steelmaking division's main displays will feature continuous casting, spray refining, and control of OH and electric-arc furnaces; those of the mechanical working division, programmed forging, wire drawing, extrusion, and a new method of rapid annealing; and the metallurgy division will include work on vacuum degassing, optical and X-ray analytical methods, magnetic properties of Si iron, and fatigue.

AMERICAN SOCIETY FOR METALS

Death of Ernest E. Thum

Ernest E. Thum, director of editorial services of the American Society for Metals, died suddenly on 10 April. He was one of the few Honorary Members of the Society, and had been concerned with the Society's extensive publishing activities since 1930. He was the first editor of *Metal Progress*, and he had been editor-in-chief since 1957.

THE INSTITUTION OF METALLURGISTS

Remuneration survey 1960

This year The Institution of Metallurgists has published its third remuneration survey; previous surveys were carried out in 1948 and 1956. The surveys do not aim at providing a substitute for age-graded salary scales for metallurgists, but at giving a clear record of the remuneration of that proportion of the Institution's members which takes part. The present survey deals with total annual earnings resulting from members' metallurgical activities at 31 August 1960. Data were requested by circulating a printed card with a printed return envelope. Entries covered age, occupation, total annual remuneration, and geographical area in which employed, and details of employment were used to compile the tables which appear in the report. The questionnaires were circulated to Fellows, Associates, and Licentiates of the Institution: 71·5% were returned completed. A brief commentary on the significance of the collated data analyses the findings in terms of each of these groups. The report deals only with salaries in the UK; the survey was extended to overseas members but a supplementary report will deal with these returns.

The report is available (3*s* post free) from the offices of The Institution of Metallurgists, 4 Grosvenor Gardens, London SW1.

THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

Electron Microscopy Group: annual conference

The annual conference of the Electron Microscopy Group will be held from 10 to 14 July 1961 at the University of Nottingham. The main topics to be discussed will be: electron microscopes and electron optics, electron microscopy of thin films, theory and scope of electron diffraction methods, and techniques and applications of electron microscopy. On 14 July there will be a symposium on 'The physics of sectioning and the embedding process'; details of this were given on page 88 of the May issue of the *Journal*. Registration is necessary and further information and application forms may be had from the Administration Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Square, London SW1.

Conference on radio spectroscopy

A joint two-day conference on *Radio spectroscopy of solids* sponsored jointly by The Institute of Physics and The Physical Society and the British Radio Spectroscopy Group is to be held at the Department of Physics, University College of North Wales, Bangor, on 21 and 22 September 1961. During the conference the Institute and Society's Guthrie lecture will be presented by Dr D. Shoenberg, F.R.S., on the subject 'The de Haas–van Alphen effect and the electronic structure of metals'. Residential accommodation will be available. Programmes and application forms will be available during July from the Administration Assistant.

Meeting on time resolution techniques

The Applied Spectroscopy Group and the Manchester and District Branch of The Institute of Physics and The Physical Society will hold a one-day joint meeting on 'Spectroscopic studies using time resolution techniques' on 16 June at The Literary and Philosophical Society, George Street, Manchester. Registration is necessary: detailed programmes and application forms are available from the Administration Assistant.

BRITISH CAST IRON RESEARCH ASSOCIATION

Publication of Russian journal

Publication of a complete translation of the monthly Russian foundry trade journal *Liteinoe Proizvodsto* has been undertaken by the BCIRA. The English title is *Russian Castings Production*, and the journal will form part of the programme of Russian translations sponsored by DSIR. The first edition, from the January 1961 issue of the Russian original, appeared in May. Publication will normally be four months after the date of the Russian version: the journal will be of about 56 pages of size 11¼in by 8in. Subscription rates for 12 issues are 10 *gns* in the UK or 12 *gns* abroad; single copies in these areas are respectively £1 10*s*, or $5 or £1 15*s*.

Enquiries and orders should be addressed to the Publications Officer, British Cast Iron Research Association, Bordesley Hall, Alvechurch, Birmingham.

ROYAL INSTITUTION OF NAVAL ARCHITECTS

Awards and prizes

The Council of the Institution has announced the following awards and prizes:

Gold Medal for any paper accepted for publication in the *Transactions* and judged by the Council to be of exceptional merit

Premium (books or instruments) to the value of 15 *gns* for a similar paper judged to merit distinction.

William Froude Medal a gold medal intended as special recognition of a conspicuous contribution to naval architecture or shipbuilding.

Samuel Baxter Prize (up to £60) an award, not necessarily to members of the Institution, which is awarded annually at the Council's discretion in recognition of the best contribution during the year to safety or efficiency in sea-going vessels.

Watts Prize (£25–£50) to a member of the Institution for proposals for improving crew or passenger accommodation in merchant ships, or life-saving apparatus. (Entries for the current prize must be forwarded to the Institution by 31 July 1961).

Requests for further details should be addressed to: Capt A. D. Duckworth, R.N., The Royal Institution of Naval Architects, 10 Upper Belgrave Street, London SW1.

SOCIETY FOR ANALYTICAL CHEMISTRY

Officers, 1961

At the annual general meeting of the Society for Analytical Chemistry, the following officers were elected for 1961: *President*: A. J. Amos; *Past Presidents serving on the Council*: R. C. Chirnside, J. H. Hamence, D. W. Kent-Jones, K. A. Williams; *Vice-Presidents:* A. L. Bacharach, J. R. Edisbury, F. C. J. Poulton; *Honorary Treasurer:* D. T. Lewis; *Honorary Secretary:* R. E. Stuckey; *Honorary Assistant Secretaries:* C. A. Johnson (Programmes Secretary), S. A. Price.

Other Members of Council: D. M. W. Anderson, B. Bagshawe, E. Bishop, S. G. Burgess, R. A. Chalmers, D. C. Garratt, E. Q. Laws, S. H. Jenkins, W. M. Lewis, C. A. Parker, D. W. Wilson, and J. T. Yardley.

Ex-Officio Members: J. Markland (Chairman of the North of England Section), A. F. Williams (Chairman of the Scottish Section), G. V. James (Chairman of the Western Section), H. C. Smith (Chairman-elect of the Midlands Section), C. Whalley (Chairman of the Microchemistry Group), G. W. C. Milner (Chairman of the Physical Methods Group), and J. S. Simpson (Chairman of the Biological Methods Group).

CONTRIBUTORS TO THE JOURNAL

W. S. Walker

G. A. V. Russell

W. S. Walker, PH.D., M.SC.(TECH.)—Consulting engineer, Campbell, Gifford and Morton Ltd. Dr Walker graduated from the College of Technology, University of Manchester, in 1933 and in 1935 he became a demonstrator in metallurgy at the university. During the same year he was awarded a Carnegie Research Scholarship by The Iron and Steel Institute. He worked for a team under Dr W. H. Hatfield at the Brown-Firth Research Laboratories, then till 1939 with the Vitkowice Steel Corporation in Czechoslovakia. After a period as production manager, light alloys, at Thos. Firth and John Brown he was seconded to the Director of Naval Construction. He was awarded his PH.D. for a thesis on thermal analysis in 1946, the year he rejoined Firth and Brown. In 1950 he became technical director of Round Oak Steel Works, and in 1957 general manager of the company. He took up his present post in September 1960. Dr Walker is an Honorary Member of the Council of The Iron and Steel Institute.

G. A. V. Russell, WH.EX., M.I.C.E., M.I.MECH.E.—Consultant engineer.

Mr Russell was born in 1897. He was educated at home and in France, Italy, and Switzerland. From 1912 to 1916 he studied part time at the Technical College, Swindon, with practical engineering training at the Swindon works of the Great Western Railway; he also studied at Sheffield University. After serving in France in the First World War as a lieutenant R.E. he joined John Brown and Co. Ltd, Sheffield, as assistant forge manager. Later he became assistant works manager, and works manager, with Davy Bros. Ltd, Sheffield; chief engineer with Lamberton and Co. Ltd, Coatbridge; and manager engineering department with Brightside Foundry and Engineering Co. Ltd. In 1929 he joined ICI Ltd, Metals Group, as deputy chief engineer and member of the management committee. In 1938 he was appointed engineering assistant to the managing director of The United Steel Companies Ltd, and later works manager of the Steel, Peech and Tozer subsidiary. He joined South Durham Steel and Iron Company Ltd in 1945 as assistant to the general manager. In 1947 he became general manager of the Cleveland works of Dorman Long and Co. Ltd, from which company he retired in 1954 to undertake consulting work for the iron and steel industry.

G. C. Wood

D. A. Melford

G. C. Wood, M.A., PH.D., A.I.M., A.R.I.C.—CEGB Research Fellow, Department of Metallurgy, University of Cambridge.

Graham Charles Wood was born in 1934 and was educated at Bromley Grammar School and at Christ's College, Cambridge, where he read natural sciences. After graduating in metallurgy in 1956, he worked in the Department of Metallurgy with Dr T. P. Hoar on the mechanism of sealing of anodic oxide films on aluminium, and obtained his PH.D. degree. At present his main research interest is the mechanism of oxidation of stainless steels and similar alloys. He is an Associate of The Institution of Metallurgists and of the Royal Institute of Chemistry, and a Member of The Institute of Metals, of the Corrosion Group of the Society of Chemical Industry, and of the Corrosion Science Society.

D. A. Melford, M.A., PH.D.—Tube Investments Research Laboratories, Hinxton Hall, Cambridge.

Dr Melford was educated at Charterhouse and at Clare College, Cambridge, where he read Metallurgy for Part II of the Natural Sciences Tripos, and obtained his B.A. in 1952. He then undertook research in the Department of Metallurgy at Cambridge on the surface tension of molten metals and alloys and was awarded the degree of PH.D. in 1956. He joined Tube Investments Research Laboratories in 1957 and began a study of the influence of residual elements in steel on hot workability. In the course of this work he collaborated with Dr P. Duncumb, then at the Cavendish Laboratory, Cambridge, in the design of an X-ray scanning microanalyser for metallurgical applications.

J. F. Whitfield, B.SC.(ENG)., M.I.MECH.E.—Chief Engineer, Round Oak Steel Works Ltd.

John France Whitfield was educated at Middlesbrough High School, before serving his engineering apprenticeship with Dorman Long and Co. Ltd, gaining an external degree of London University in 1939. While with the company he became technical en-

gineer, and assistant to the chief engineer; he subsequently specialized in rolling mills, and has published work on this subject.

In 1942 he took up the post of assistant chief engineer, Laporte Chemicals, now Laporte Industries Ltd, heavy chemical manufacturers, Luton, and in 1947 became chief engineer to Birmetals Ltd, Birmingham.

After two years as general manager to B. Thornton Ltd, Huddersfield, he took up his present position in 1954.

Mr Whitfield is a former member of the Rolling Mill Committee and the Rolling Mill Research Sub-Committee of The British Iron and Steel Federation.

NEWS OF SCIENCE AND INDUSTRY

Obituary: Professor C. W. Dannatt

The death occurred in London on 9 April of Professor C. W. Dannatt, Professor Emeritus of the Royal School of Mines, London, and a Fellow of Imperial College. He was 68.

A graduate of the Royal School of Mines, Professor Dannatt returned there in 1923 as a research assistant, then joined the teaching staff, where he specialized in metallurgical analysis and extraction metallurgy. He became Assistant Professor and London University Reader in Metallurgy in 1937. During the Second World War when the department was attached to the University College of Swansea Professor Dannatt was acting director of the department. He was appointed to the Chair when the department returned to London in 1945, and he resigned in 1957.

Dictionary of Commercial Expressions

A 150-page English–Russian Russian–English pocket dictionary of commercial expressions has recently been published by the British Iron and Steel Federation. Copies are available from the Information Office, Steel House, Tothill Street, London SW1.

Appointments

The Electric Steelmakers Guild
The officers of the guild for the year 1961–62 are: *President* W. Keen, *Vice-President* R. S. Howes, and *Secretary* F. Cranksaw.

Steel Company of Wales
Viscount Amory of Tiverton has been elected a director of The Steel Company of Wales.

The United Steel Companies Ltd
Mr A. R. Robertson has been appointed registrar of The United Steel Companies Ltd.

BCIRA
Mr P. Lambert has been appointed head of the engineering section of the British Steel Castings Research Association.

New safety film

Michigan (Great Britain) Ltd have produced a film featuring the correct handling of heavy constructional equipment. Operatives are shown how to avoid unnecessary accidents, and assistance is given to those concerned in ensuring that the high productivity rate of the Michigan equipment is set and maintained. This 16-mm film is in full colour and the running time is about 20 min. Earlier films available from the company are: 'Dozer line 1959' (rubber-tyred tractor dozers); 'Michigan pipe handler' (varying aspects of pipe handling); 'Bonus buckets' (tractor shovels in action); 'Michigans on the motorway' (equipment on the Doncaster by-pass).

Michigan users and professional institutes may borrow these films. Enquiries should be made to the company at PO Box 3, Camberley, Surrey.

Fire fighting in industry

Since 1 December 1960, factory occupiers have been required by the Factories Act 1959 to provide adequate fire-fighting equipment, efficiently maintained, and in a convenient position well known to all workers. A recent Ministry of Labour booklet, 'Fire fighting in factories', points out that the necessary equipment will vary according to the factory's purpose, the nature of its buildings, and its general standard of 'house keeping'; and advises on the extinguishing equipment appropriate to particular risks, and on installation, location, and maintenance of equipment.

Fire brigades in the UK deal annually with over 7000 outbreaks of fire in industrial premises, and the material losses caused by these amount to over half the total damage due to fire, while more than 100 persons lose their lives or suffer injury.

The booklet (Safety, Health, and Welfare Series, No.10, HM Stationery Office; 2*s*) urges any occupier or owner uncertain about his particular needs to consult HM Factory Inspectorate or the Chief Officer of the Fire Authority concerned.

Company News

Moxey Ltd, West Bromwich, and *Laeis-Werke*, Trier, Germany, are to co-operate in the building of plant for the production of dolomite bricks for lining oxygen-blown steel-making furnaces.

AEI-Birlec Ltd, Birmingham, and *Major Electric Furnaces Pty Ltd*, Melbourne, (Canada) Ltd) will control and promote the marketing in Canada of all products of the Hadfields group.

AEI-Birlec Ltd, Birmingham, and *Major Electric Furnaces Pty Ltd*, Melbourne, Australia, have agreed to set up in Melbourne a new company to be known as Birlec-Major Pty Ltd, with offices in Chesterville Road, Moorabbin, Melbourne.

The Morgan Crucible Group has published a list of subsidiary companies as after the recent reorganization of the group. The folder gives the addresses and details of subsidiaries with specialized production, in the UK and overseas.

Foseco-Fordath Ltd is a joint company formed by Foseco International and the Fordath Engineering Company to license the manufacture and marketing of the Fordath range of core binder products outside the UK.

New plant and equipment

Dewhurst and Partner Ltd, Hounslow, have announced a new range of unit contactors, the H series available in 50, 100, and 200 A versions for ac or dc working; each unit is available as a single or multi-pole unit. Rated to BS8.775, they are described in technical publications PD 10–11 available from Public Relations Dept., Dewhurst and Partner Ltd, Inverness Works, Hounslow, Middlesex.

British Oxygen are to build a tonnage oxygen plant at a cost of nearly £750000 for the Warren Lane Works, Scunthorpe. There will then be three such plants in the area, and they will supply oxygen to Appleby-Frodingham Steel Co., Richard Thomas and Baldwins, Redbourn, and John Lysaght's Scunthorpe works.

The General Electric Co. Ltd, at Erith, is constructing a Pennsylvania spider-mounted Bradford breaker to be used for crushing coal in the coking plant being built at the Spencer works of Richard Thomas and Baldwins Ltd.

English Electric (Metal Industries Division) is producing a new sheet metal classifier for quality control in sorting sheared sections of cold strip.

Plenty and Son Ltd, Newbury, have supplied eight identical pumps to The Steel Company of Wales Ltd, Port Talbot, and Richard Thomas and Baldwins Ltd, Ebbw Vale. These are for the first commercial blast-furnace oil-firing installations in the UK. The makers claim that their pumps have two advantages: their 'Universal' pump is capable of variable flow adjustment, and is not influenced by pressure changes in the discharge line. The pumps have been supplied through Shell-Mex and BP.

A new version of the multi-point electronic strip chart recorder to enable ten alternative points to be measured and recorded on one instrument, is announced by *Honeywell Controls Ltd*. Known as the Universal ElectroniK multi-point recorder, it increases the scope of recording different numbers of variables on the same instrument. Range and compensation can also be altered.

US Steel Corporation are to build a 60-in continuous galvanizing line at their Central Operations mill at Gary, Indiana, where two lines are already operating. The new line, which will be able to produce aluminized as well as galvanized sheet, is scheduled for completion by mid-1962.

Contract News

Thomas Smith and Sons (Rodley) Ltd have received orders for nine machines (Smith '12' and '21' excavators) for Switzerland; an order for a M.E.11 truck-mounted crane from North Borneo; and from the Clyde Engineering Company of New Zealand an order for three Smith '12' machines.

Stewarts and Lloyds of Canada have been awarded contracts worth about £670000 to supply steel pipe for Canada's natural gas projects.

The General Electric Co. Ltd has received an order valued at £139000, for the supply and installation of a turbo-blower at the Cleveland works of Dorman Long (Steel) Ltd.

Simon Carves of Canada Ltd have received a contract to supply coal preparation plant for the Crow's Nest Pass Company, British Columbia. The *Automatic Coal Cleaning Co. Ltd*, Carlisle, will supply the feldspar jig washbox.

Head Wrightson (Australia) Ltd have received orders worth £3¼ m. for design and completion of plant at Whyalla, South Australia, for the Broken Hill Pty and Australian Iron and Steel. The order includes the supply of an oxygen steelmaking plant.

Associated Electrical Industries Ltd (Heavy Plant Division) have received an order worth nearly £1 m. for electrical equipment for four rolling mills to be installed at English Steel Corporation's new Tinsley Park Works, Sheffield.

South Durham Steel and Iron Company have received orders worth over $6 m. for 180 miles of steel pipes; the orders are from Libya, Alberta, B.C., and the Middle East.

The Brightside Foundry and Engineering Co. Ltd have received a contract worth over £1½ m. from Duport Ltd for the construction of a merchant bar mill; the mill is scheduled for operation in 1963.

INDUSTRIAL PUBLICATIONS RECEIVED

The Messer Story, an attractive brochure published by Messer Industrial Engineering Ltd, surveys the field of welding engineering, with particular emphasis on the importance of oxygen cutting, arc welding, inert gas welding, and deseaming.

Requirements for the protection of persons employed in factories and other places against ionizing radiations and other hazards arising from the use of radioactive substances are laid down in Preliminary Drafts of Regulations published recently by the Ministry of Labour as 'Unsealed Radioactive Substances Regulations' (HMSO, 1*s* 3*d*), and 'Ionizing Radiations (Sealed Sources) Regulations, 1961' (HMSO, 9*d*).

Max Arc give details of their latest welding set in a leaflet 'The 0·200 Electric Arc Welder'.

Industrial relations handbook has been revised by the Ministry of Labour; a manual for all concerned with industrial relations, it is published by H.M. Stationery Office, price 5*s* 6*d*.

Johnson Matthey have issued a revised and enlarged series of data sheets, the 1740 series, on their range of platinum-wound electrical resistance furnaces and control units.

Geoscience Instruments Corporation have issued a new catalogue of abrasive supplies for equipment used in laboratory and machine shop.

Lectromelt Furnaces give details of various GWB furnaces in a recent leaflet.

Review of progress 1960 surveys the past year from the point of view of The United Steel Companies Ltd.

CHANGES OF ADDRESS

Exactor Ltd have moved to Sterling Works, Blacknell Lane, Crewkerne, Somerset.

Kestner Evaporator and Engineering Co. Ltd are transferring their London works from New Cross to Greenhithe.

FORTHCOMING CONFERENCES

FBI exhibition in Mexico

The Federation of British Industries is to hold an all-British exhibition in Mexico City. 'British Equipment for Mexican Industry' will be held from 29 September to 15 October 1961, and will include raw and semi-finished materials, tools, production machinery, mechanical handling and factory transportation, weighing and packaging, measuring and other instruments, and a wide variety of engineering products.

Effluent and water treatment exhibition

The second effluent and water treatment exhibition will be held at the Seymour Hall, London W1, from 31 October to 3 November 1961. Technical developments in water treatment and recovery, treatment of waste will be featured. There will be convention papers from overseas experts in the field. Further particulars are available from P. I. Craddock, Dale Reynolds Publicity, 2 Broad Street Place, London EC2.

National Maintenance Exhibition and Conference 1961

The first large-scale conference on maintenance ever held in the UK will take place in the Central Hall, Westminster from 13 to 16 November 1961.

The conference programme has been carefully selected by a committee of practising maintenance engineers and will cover aspects of maintenance organization and practice. At each of the four main morning sessions, when all delegates will assemble in one hall, papers will be presented. It is expected that engineering and production directors, works directors, and managers, as well as maintenance and works engineers, will attend the conference.

EFCE Third Congress

A symposium on the physics and chemistry of high pressures sponsored by the Society of Chemical Industry will form part of the third congress of the European Federation of Chemical Engineering at Olympia, London, in 1962. The Congress, from 20 to 28 June 1962, will include the following topics: process optimization, interaction between fluids and particles, the handling of solids, and the physics and chemistry of high pressures. The international symposium on the last subject will cover theoretical, experimental, and applied work on high pressures (1000 atm upwards), and the subjects discussed will include changes of phase, study of electrical, chemical, and other physical properties, and work on new techniques, equipment, and design. Suggestions for papers for inclusion in the programme are invited and should be sent, with title and summary, as soon as possible, to the General Secretary, Society of Chemical Industry, 14 Belgrave Square, London SW1.

DIARY

4–9 June 6TH INTERNATIONAL CONFERENCE ON HOT DIP GALVANIZING—Interlaken, Switzerland.

5–7 June INTERNATIONAL MEETING ON WATER RESEARCH (CORROSION THROUGH INDUSTRIAL WATER)—Liège.

5–7 June IRONMONGERS EXHIBITION—Spa Hotel, Scarborough.

9–17 June 30TH MEETING OF THE EUROPEAN FEDERATION OF CHEMICAL ENGINEERING (INCLUDING 4TH INTERNATIONAL SYMPOSIUM ON GAS CHROMATOGRAPHY)—Frankfurt.

12–15 June BRITISH ELECTRICAL POWER CONVENTION—Winter Gardens, Eastbourne.

15–16 June BISRA LABORATORIES—Open days Hoyle Street, Sheffield 3.

15–24 June INTERNATIONAL CONSTRUCTIONAL EQUIPMENT EXHIBITION—Crystal Palace, London.

15–26 June INTERNATIONAL TRADE FAIR—Bordeaux, France.

15–29 June 8TH NUCLEAR AND ELECTRONIC CONGRESS AND EXHIBITION—Rome.

16 June APPLIED SPECTROSCOPY GROUP and MANCHESTER AND DISTRICT BRANCH OF INSTITUTE OF PHYSICS AND PHYSICAL SOCIETY—Joint meeting on 'Spectroscopic studies using time resolution techniques'—Manchester (*see* col.1, p.182, this issue).

19–22 June LABORATORY APPARATUS AND MATERIALS EXHIBITION—Royal Horticultural Society New Hall, Westminster.

21 June–5 July INTERNATIONAL TRADE FAIR—Trieste, Italy.

27–30 June 1ST BRITISH CONFERENCE ON 'SOCIAL AND ECONOMIC EFFECTS OF AUTOMATION'—Harrogate.

6–12 July INSTITUTION OF ELECTRONICS—Annual exhibition—College of Science and Technology, Sackville Street, Manchester 1.

5–15 July BUILDING AND PUBLIC WORKS EXHIBITION — Belle Vue, Manchester.

7–29 July SOVIET EXHIBITION—Earl's Court, London.

10–14 July ELECTRON MICROSCOPY GROUP—Annual Conference—University of Nottingham.

14 July ELECTRON MICROSCOPY GROUP—Symposium '*Physics of sectioning and the embedding process*'—University of Nottingham.

23–29 July ROYAL INSTITUTION OF NAVAL ARCHITECTS—Summer school for teachers of naval architecture—College of Aeronautics, Cranfield.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on page 88 of the May 1961 issue of the *Journal*.

When ordering, please quote the number in bold type.

Creep in semi-annular plates. (From Russian.) BOGUSLAVSKII, P. Ya., *Teploenergetika*, 1958, (2), pp.56–61. (£4 5*s*. 0*d*.) **[1441**

Design and operation of rolling mill furnaces during the last four decades. (From German.) BORCHERS, L.-O., *Stahl Eisen*, 1959, *79*, Oct. 29, pp.1591–1601. (£7 5*s*. 0*d*.) **[1552**

The forgeability of ferritic steels for superheater tubes. (From Czech.) BIHET, O. L., and CAUBO, M., *Hutnické Listy* (Prague), 1959, *14*, (12), pp.1103–1105; *Rev. Mét.*, 1960, *57*, July, pp.607–612. (£4 5*s*. 0*d*.) **[1670**

Determination of stresses during the forming of metals by pressure. (From Russian.) TARNOVSKII, I. Ya. *et al.*, Obrabotka metallov davleniem (sbornik statei). Vypusk tretii. (The working of metals by pressure (Collection of articles, issue 3), Moscow, *Metallurgizdat*, 1954, pp.5–22. (£4 10*s*. 0*d*.) **[1876**

Forces, moments, and stresses in rolling mills. An investigation of vibration. (With a contribution by P. Blain.) (From German.) LIEBOLD, R., *Freiberger Forschungsh. Met.*, 1960, (B*48*), pp.5–25. (£6 5*s*. 0*d*.) **[1941**

The operation of a blast-furnace of 1700 m^3 volume at Espérance-Longdoz, Liège. (From French.) MAERTENS, P. *et al.*, *Rev. Univ. Min.*, 1960, *103*, June, pp.272–294. (£10) **[1952**

The international ore market. Some technical and economic trends. (From Swedish.) LUNDBERG, A. S. (reprint from) *Blad Berg. Vänner* (Stockholm), 1960, (1), pp.17–47. (£6 15*s*. 0*d*.) **[1967**

Quantitative X-ray fluorescence analysis of multi-component systems. (From German.) PREIS, H., and ESENWEIN, A., *Schweizer Archiv.*, 1959, Nov., pp.415–418. (£2 10*s*. 0*d*.) **[1972**

Contribution to the study of embrittlement in special steels: analogy of various types of brittleness observed in ferritic and austenitic steels. (From French.) CASTRO, R., and GUEUSSIER, A., *Rev. Mét.*, 1960, *57*, Aug., pp.715–724. (£6) **[1978**

Practical results obtained regarding knurled roll passes. (From German.) BARTH, O., *Neue Hütte*, 1960, *5*, Aug., pp.488–490. (£2 5*s*. 0*d*.) **[1980**

Electrical weighing machines in steelworks. (From German.) OEMIGK, J., *Stahl Eisen*, 1960, *80*, Oct. 13, pp.1411–1414. (£3 5*s*. 0*d*.) **[1999**

Breakages of crane hooks and ladle yokes and how to avoid them. (From German.) WILL, G., *Stahl Eisen*, 1954, *74*, Aug. 12, pp.1062–1069. (£5 10*s*. 0*d*.) **[2001**

The neutral angle in hot and cold rolling processes. (From Polish.) WUSATOWSKI, Z., *Arch. Gornictwa i Hutnictwa*, 1955, **3**, (1), pp.11–42. (£6) **[2005**

A rapid flame-photometric method for the determination of Na_2O and K_2O in various refractories. (From German.) KONOPICKY, K., and SCHMIDT, W., *Ber. Deutsch. Keram. Ges.*, 1960, Aug., pp.368–371. (£1 15*s*. 0*d*.) **[2029**

A practical example of non-destructive testing with iridium-192 on a welded revolving tubular cement kiln at the building site at Karsdorf. (From German.) TSCHORN, G. *et al.*, *Wissenschaftliche Z. der Hochschule für Schwermaschinenbau Magedeburg*, 1959, *3*, (2), Nov., pp.215–223. (£5 5*s*. 0*d*.) **[2033**

The production and application of mangesia alumina bricks for roofs of open-hearth furnaces in China. (From Chinese.) GUAN, Zong-Shan, and WANG, Yun-He., *Gangtie*, 1958, Sept., pp.19–24. (£14) **[2038**

The formation of cube texture in an iron-silicon alloy. (From Chinese.) CHOU, Pang-Hsin *et al.*, *Acta Physica Sinica*, 1960, March, pp.155–159. (£9) **[2051**

Grain growth produced by slight deformation of rimming steel sheet. Its effect on magnetic properties. (From Italian.) BERRUTI, V., and SOMMACAL, B., *Met. Ital.*, 1959, *51*, April, pp.129–138. (£4 5*s*. 0*d*.) **[2052**

Study of the strain-ageing of mild steel and of high-purity iron by age-hardening and reversion tests. (From German.) NACKEN, M., and HELLER, W., *Arch. Eisenhütt.*, 1960, *31*, Feb., pp.103–111. (£5 10*d*. 0*s*.) **[2054**

Structural phenomena related to the hot rolling of rimming steel sheet. (From French.) BERRUTI, V. *et al.*, *Rev. Mét.*, 1960, *57*, Nov., pp.1019–1031. (£4 15*s*. 0*d*.) **[2055**

The importance of physico-chemical investigations to the development of granulated slag technology. (From Polish.) ROGOZINSKI, T., *Hutnik* (Poland), 1960, *27*, (3), pp.109–114. (£5 10*s*. 0*d*.) **[2064**

Problems in the design of casting and transport bogies for ingots and slabs. (From German.) KURSCHEIDT, W., *Stahl Eisen*, 1961, *81*, Jan. 5, pp.58–60. (£2 5*s*. 0*d*.) **[2072**

Safety in the use of oxygen. (From German.) VOIT, R., *Linde Ber., aus Technik und Wissenschaft*, 1960, (9), pp.46–55. (£5 5*s*. 0*d*.) **[2080**

New ways of intensifying metallurgical processes. (From Russian.) BARDIN, I. P., *Izvest. AN Otdel, Tekkn. Met. i Toplivo*, 1959, (6), pp.3–7. (£3 15*s*. 0*d*.) **[2083**

Pipelines transporting solid matter: the metallurgists' point of view. (From French.) BIHET, O. L., *Centre Belge d'Étude et de Doc. des Eaux*, 1960, March, pp.76–81. (£3) **[2088**

Cleaning of fume from electric arc furnaces. (From French.) SEPTIER, L., *Centre Doc. Sidér.* (Paris), 1958, *15*, (7), pp.1479–1486. (£2) **[2092**

Mean free path in problems of acoustic and thermal radiation. (From Italian.) CODEGONE, C., *Atti della Accad. delle Sci. di Torino*, 1954–55, *89*, pp.66–67. (15*s*. 0*d*.) **[2096**

Experiments on the thermal radiation from flames. (From Italian) CODEGONE, C., *Atti della Accad. delle Sci. di Torino*, 1954–55, *89*, pp.345–349. (£1 15*s*. 0*d*.) **[2097**

The determination of oxygen in liquid Thomas steel. Techniques for taking a liquid sample and analysing for the gas. (From French.) MABOT, J., and HARVENG, I., *Rev. Mét.*, 1960, *57*, Nov., pp.991–997. (£3 5*s*. 0*d*.) **[2106**

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

CONTENTS

Note: The letters *a*, *b*, and *c* refer to the three columns on the page concerned.

	PAGE
MINERAL RESOURCES	185*a*
ORES—MINING AND TREATMENT	185*b*
FUEL—PREPARATION, PROPERTIES AND USES	186*c*
AIR POLLUTION, DUST AND SMOKE	187*a*
TEMPERATURE MEASUREMENT AND CONTROL	187*b*
REFRACTORY MATERIALS	187*b*
IRON AND STEEL, GENERAL	188*a*
BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG-IRON	188*b*
PROPERTIES, TREATMENT AND USE OF SLAGS	189*b*
PRODUCTION OF STEEL	189*c*
PRODUCTION OF FERRO-ALLOYS	194*b*
FOUNDRY PRACTICE	194*b*
VACUUM METALLURGY	199*a*
REHEATING FURNACES AND SOAKING PITS	199*a*
HEAT-TREATMENT AND HEAT-TREATMENT FURNACES	199*b*
FORGING, STAMPING, DRAWING AND PRESSING	201*b*
ROLLING MILL PRACTICE	202*c*
MACHINERY AND SERVICES FOR IRON AND STEEL PLANT	203*b*
WELDING AND FLAME-CUTTING	203*c*
MACHINING AND MACHINABILITY	205*a*
CLEANING AND PICKLING	205*b*
PROTECTIVE COATINGS	206*a*
CLAD SHEET AND HARD-FACING	208*b*
POWDER METALLURGY	208*b*
FERRITES, CERMETS AND CARBIDES	208*c*
PROPERTIES AND TESTS	208*c*
METALLOGRAPHY	217*c*
CORROSION	220*b*
ANALYSIS	225*b*
INDUSTRIAL USES AND APPLICATIONS	226*b*
HISTORICAL	226*c*
ECONOMICS AND STATISTICS	227*a*
MISCELLANEOUS	227*a*
BOOK NOTICES	227*b*
NEW PUBLICATIONS	228*b*

* Abstracts, the reference to which is marked with an asterisk, are or are to be made available as translations.

ABSTRACTS

These abstracts are also available on index cards in advance of publication in the *Journal*, each abstract being classified under the Universal Decimal system (UDC). Details and subscription notes can be obtained from the Secretary, The Iron and Steel Institute.

MINERAL RESOURCES

A manganese occurrence in Wigtownshire A. Paterson-Nisbet (*Min. Mag.*, 1959, **101**, Dec., 318–320) A deposit at the base of a raised beach is described. The sample assayed, moisture 57·07, MnO_2 26·58%. With dried ore, 61·9%MnO_2 was found. It was not found possible to estimate the extent of the ore area.

The Grand Lahou (Ivory Coast) manganese deposit J. Peccia-Galletto (*Ann. Mines*, 1960, **165**, Nov., 712–720) The small deposit of the Mokta Co., first prospected in 1956 and yielding 100000 t of 47%Mn per year, is described with details of location and illustrations.

Iron ore deposits and aeromagnetic anomalies near Tarcoola [S. Australia] G. F. Whitten (*Mining Review*, 1958, June 30, 22–27).

The mining industry in Southeast Asia D. F. Coolbaugh (*Min. Eng.*, 1960, **12**, Oct., 1103–1106) Fe, W, Mn, and other ore reserves are mentioned.

Iron ore R. B. Elver (*Can. Mines, Can. Mineral Industry*, 1959, *Review* 12, pp.18).

Compositional characteristics and equilibrium relations in mineral assemblages of a metamorphosed iron formation R. F. Mueller (*Amer. J. Sci.*, 1960, **258**, Summer, 449–497) A Quebec iron formation is described which is probably a metamorphosed equivalent of the Fe-bearing sediments of the Labrador trough. The mineral assemblages contain, talc, quartz, actinolite, Ca-pyroxene, cummingtonite, magnetite, haematite, calcite, and dolomite; 76 spectrographic analyses are given of the rocks which are essentially members of the system CaO–MgO–FeO–O–SiO_2–H_2O–CO_2. The compositional relationship is generally consistent with phase rule considerations and may be elucidated by functions based on the coupling of chemical reactions between minerals (17 refs).—C.V.

Iron deposits of Wabush Lake, Labrador R. D. Macdonald (*Min. Eng.*, 1960, **12**, Oct., 1098–1102) With maps and an historical account of exploration and of methods used.

Utilization of Allard Lake ilmenite E. W. Montgomery (*Min. Mag.*, 1959, **101**, Dec., 352; from *Western Mines & Oil Review*, Oct.) Those titaniferous-iron ores are situated in Quebec province and the main ore-body contains >100 000 000 t ~36%Fe and 32%TiO_2. Ilmenite and haematite occur together in a ratio of 2:1 and anorthosite. Some MgO (3%) replaces FeO in the lattice and Fe-oxides are present as magnetite. Intergranular pyrite is found throughout and accounts for 0·3%S. On account of the Fe content, this ore is unsuitable for the pigment industry. The smelting processes are described.—C.V.

Cebolla Creek titaniferous iron deposits, Gunnison County, Colo. K. C. Rose and S. S. Shannon jun. (*US Bur. Mines, Rept. Invest.*, 5679, 1960, pp.30) Trial borings are noted.

ORES—MINING AND TREATMENT

Semi-automatic lift in the underground ore mine W. Holtschke and O. Marx (*Neue Hütte*, 1960, **5**, Dec., 716–720) A description of the design and installation of an electrically driven semi-automatic lift with provision for interior and exterior control, at the mines of VEB Zinnerz Altenberg.

Belt conveyors in metal mines. I (*Mining J.*, 1960, **225**, Sept. 23, 332–334) A general discussion; Dragonby and Santon are given as examples and it is stressed that the conditions are ideal for a conveyor system. Even so, certain problems have been met with and their solutions are presented.—C.V.

Iron ore mining at Kiruna S. Brand (*Iron Coal Trades Rev.*, 1960, **181**, Nov. 25, 1171–1172) These open-cast mines in the north of Sweden are now being converted to underground mining.—C.V.

Re-opening of the Iron Baron–Iron Prince iron deposits Broken Hill Proprietary Co. Ltd. (*Mining Review*, 1958, June 30, 16–21)

The size of the trans-oceanic market for iron ore G. de Paiva (*Eng. Min. e Met.*, 1960, **32**, Aug., 103) It is pointed out that the 4×10^8 t of ore exported by Brazil represents about 7% of the trans-oceanic market and not 1% as commonly believed. This could be trebled, without much effect on the reserves, to bring in valuable currency for development purposes.

Cobalt V. N. Schneider (*Can. Mines, Tech. Paper*, 1959, Rev. No.8, pp.7) No Co ores were mined in Canada in 1959; production was from by-products from the Ag-ores and from the smelting and refining of Ni–Cu ores. World mine production, consumption, and uses are summarized, prices and tariffs being set out.

Canada stimulates iron ore exports O. H. Leonardos (*Eng. Min. e Met.*, 1959, **29**, Jan., 5–6) A brief account of Canadian ore production and exports is given.—P.S.

Brazil and the world market for iron ore G. Mendes Barros (*Eng. Min. e Met.*, 1960, **31**, May, 246, 248) A book review.

Colombia: Production of iron ore and coal for the Paz del Rio Steel Co. (*Bull. ILAFA*, 1960, **1**, Oct., 10) Colombia Government Geological Dept. views on existing and prospective deposits of iron ore and coal are reported.

Chile: New steel ships for Huachipato (*Bull. ILAFA*, 1960, **1**, Oct., 12) Two new ships, the *Elqui* and the *Illapel*, each of 14 000 t burthen, and built in Hamburg, were placed in service by the Cia. Sudamericana de Vapores, in conjunction with the Cia. de Acero del Pacifico, in August 1960, for the transportation of iron ore and limestone for the plant of the Cia. de Acero del Pacifico at Huachipato.—S.H.-S.

Ore crushing in the Lorraine iron ore mines Bresteau (*Centre Doc. Sid. Bull.*, 1960, (10), 2187–2197) The changes brought about by the introduction of primary and secondary crushing in the Lorraine field is discussed with reference to the working and productivity of the mines and the sizing of the product.

Mineral dressing: Old and new E. J. Pryor (*Min. Mag.*, 1959, **101**, Dec., 297–308) Development over the last 50 years is described.

Automatic thickener control at Marmora mine W. M. Aubrey jun. (*Min. Eng.*, 1960, **12**, Sept., 1009–1012) The thickener feed control and filter circuits are diagrammatically set out; the functions of the controls are to meter into the thickener an amount of magnetite concentrate equal to that removed for filtering and to maintain within the limits the desired sludge level in the thickener; this ensures a thickener underflow of constant density.

Application of the law of mass action to ore flotation F. J. Laczner (*J. Sci. Ind. Res.*, 1960, **19B**, Nov., 425–430) The law of mass action can be applied to this problem to determine flotation efficiency and the amount of gangue mineral in the concentrate can be determined at any time during the flotation process. The equation presented can be applied to establish flotation values for various ores.—C.V.

Ferrograde concentrates from Arkansas manganiferous limestone M. M. Fine (*AIMME*,

Trans. Soc. Mining Eng., 1959, **214**, 810–811) Tests on tabling and flotation were carried out, also some leaching trials. Satisfactory concentrates though in the somewhat low recoveries and, from tabling, high P content were obtained.

Dry concentration of magnetic ores on the Sala-Mörtsell separator E. B. Johanson (*Mining J.*, 1960, **255**, Sept. 30, 356–357) Typical flow sheets for dry and wet separation and dry grinding and separation are shown. The difficulties in obtaining a clean concentrate with very fine material in the Aerofall mill circuit are mentioned; these are avoided in the present system as clean tailings are always obtained but, owing to electrostatic forces, the fine ground concentrate must sometimes be run over a wet washing separator.—C.V.

High-intensity magnetic separation of iron ores O. E. Palasvirta (*AIMME, Trans. Soc. Mining Eng.*, 1959, **214**, 1244–1248) The design of a separator with a non-uniform field and trials on various ores are considered. Some apparently simple ores cannot be concentrated by this method.

Ore concentration plant in arctic Sweden (*Min. J.*, 1960, **255**, Oct. 14, 413) The new installation at the LKAB iron ore mines at Malmberget is described. An output of 6×10^6 t by 1965 is aimed at, the concentration plant handling 1 200 000 t per annum of coarse dressed ore up to 72%Fe. Working staff has been reduced from 70 to 30 and the capacity of the pelletizing works is doubled to 350 000 t per year. Underground galleries cover some 190 miles. After crushing and sorting below ground, the ore arrives on the upper deck of the eight-floor structure; it proceeds stepwise downwards to an ultimate granular size of 0·08 mm (70–71·3%Fe, moisture 8%).—C.V.

Laboratory beneficiation of East Texas limonite–siderite iron ores H. E. Powell and W. M. Dressel (*US Bur. Mines, Rept. Invest.*, 5647, 1960, pp.14) Sampling and preliminary work is reported.

Iron sand and its utilization T. Ichikawa (*Suiyokwai-Shi*, 1958, **13**, Sept., 451–455) Iron sand found in Japan is one of the useful ores, containing valuable elements such as TiO_2 and V. Firstly, the size of the deposit is estimated from the bulletin issued from the Bureau of Mines, and mining and dressing methods are discussed. Secondly, production of pig iron from the sand in the electric furnace, production of low-P pig iron and highly purified pig iron as well as the base metal of special steel from molten pig iron has been investigated. Thirdly, recovery of V and production of high TiO_2 slag is studied. Finally utilization of the furnace gas is described. Thus, the author indicates briefly how to utilize the iron sand found in Japan.—R.S.F.C.

Electrolytic separation studies of nickel and cobalt from Nicaro-plant products M. J. Ferrante, P. C. Good, and P. M. Gruzensky (*US Bur. Mines, Rep. Invest.*, 5394, 1958, May, 1–30).—C.F.C.

Separation of chloride vapours during ilmenite chlorination V. A. Nieberlein (*US Bur. Mines, Rep. Invest.*, 5602, 1960, 1–11) $TiCl_4$ and $NbCl_5$ were obtained pure by passing through a packed absorption column without distillation.

Micrographic studies of the reduction of jaspilite J. B. Lean and K. J. Tucker (*BHP Tech. Bull.*, 1960, **4**, Nov., 8–14) Jaspilite is a fine-grained haematite–quartzite from which the haematite can be leached by prolonged immersion in acid leaving a quartz skeleton. It could be anticipated that reduction would take place by diffusion through the pores but that a relatively long time would be required. However, during this process, microcrystalline cracking allows better access of gases with the result that better reduction values are obtained than with high-grade lump haematite; this facilitates magnetic liberation and reduces grinding costs. The optimum operating temp. is 600°, but balanced gas compositions are required to avoid over-reduction to wüstite at this temp. and the moisture content of the reducing gases must be kept to a minimum; at 550° in dry H_2 there is a higher reduction rate but this is at the expense of over-reduction to Fe and in the absence of natural gas or other cheap source of H_2 would be less commercially attractive. High temp. are undesirable as reduction rates decrease and over-reduction to fayalite occurs.—C.V.

Pilot plant for magnetic reduction of jaspilite J. R. J. Edwards (*BHP Tech. Bull.*, 1960, **4**, Nov., 33–35) Reduction is carried out in the presence of CO and H_2 in a shaft furnace. Any reduction to lower non-magnetic oxides will result in loss of Fe in subsequent concentration process but this over reduction can be minimized by adjustment of the ratio of reaction products (CO_2 and H_2O-vapour) to reducing gases in the furnace atm. so that the system tends to an equilibrium in which magnetite is the stable phase. This is attained by recirculating a major portion of the exhaust gases balanced by a controlled quantity of fresh reducing gas. This large volume of gas abstracts heat from the reduced ore and imparts heat to the incoming fuel so that both ore and gas leave the furnace at a relatively low temp. giving good heat economy. A schematic diagram of the shaft furnace and recirculating gas system is given. The production of the reducing gas and instrumentation are described together with a tabulation of the operating conditions.—C.V.

The reactivity of coke and ore–coke mixtures A. T. Khvichiya (*Izvest. VUZ Chern. Met.*, 1960, (2), 21–24) The reactivity of these materials was investigated by the simple method of passing a current of CO_2 through a 100 mm thick layer of 8–10 mm particle size. The composition of the escaping gases was then analysed. Tables are given for six different types of coke and for six mixtures of manganese and iron ores each with different proportions of coke.

Workington Iron and Steel 'focus' sinter plant (*Iron Coal Trades Rev.*, 1960, **181**, Dec. 16, 1321–1323) This sinter plant is being brought up to its rated capacity of 12 500 t/week. A general description of the plant is given.—C.V.

Progress achieved at the Société Metallurgique de Normandie by the sintering of fines, and a new blast furnace P. Jourde (*Centre Doc. Sid. Tech.*, 1960, (10), 2253–2267) A detailed account is given, with flow sheets to show how ore preparation and sintering has increased output and decreased coke consumption.—A.D.H.

Hearth sintering A. Roederer (*Centre Doc. Sid. Bull.*, 1960, (10), 2199–2207) The status of batch hearth sintering processes in France, the problems of defining the quality of the feed, and the product and running of the plant are discussed.—A.D.H.

Effect of uneven distribution of the grain size on the temperature in the strand sintering of iron ore O. Steinhauer and K. Zehe (*Stahl Eisen*, 1961, **81**, Jan. 19, 80–95) A device is described that permits measurement of temp. at many points during the normal operation of a sinter belt without stopping the conveyor. By arranging several thermocouples across the belt and at different heights it was possible to follow the temp. distribution and to establish relations between temp. and uneven permeability of the sinter. The results obtained are presented in many graphs and are discussed.

Effect of recirculation sinter on the down-draft sintering of iron ore H. Rausch and F. Cappel (*Stahl Eisen*, 1961, **81**, Jan. 19, 96–102) The effect of recirculation sinter on sinter strength, oxidation level, and porosity of the sinter obtained in a down-draught grate-type sintering machine has been studied and the results obtained are compared with results from sintering in pans. It was found that addition of recirculation sinter has a beneficial effect, as long as it is added in amounts varying between 30 and 60% of the new ore.—T.G.

On the permeability of pyrite ash charges for sintering H. Sawamura, K. Akamatsu, S. Miyazaki, and M. Yakushizi (*Suiyokwai-Shi*, 1955, **12**, June, 485–488) A kind of pyrite cinder was charged in a small experimental sintering box and the permeability of the charge was measured. The grain size distribution of pyrite cinder and the amount of water in the charge were varied. The influence of return sintered ores and coke breeze, which were added to the charge, on the permeability was also examined.

FUEL—PREPARATION, PROPERTIES AND USES

Coal preparation and its future J. E. Chick (*Manchester Assoc. Eng.*, 1959–60, (5), pp.29) The demands of the consumer, the washability characteristics of the raw coal, the limitation and efficiency of washing plants, capital costs, mining methods, and transport of coal to the washery are reviewed.—C.V.

Selectivities of laboratory flotation and float-sink separations of coal J. B. Gayle and A. G. Smelley (*US Bur. Mines, Rep. Invest.*, 5691, 1960, pp.19) In flotation tests NaCl, and alcohol-type frothing agent and kerosene pine oil mixture were used on seven coking coal samples from four different beds. Yield-S curves for flotation and float-sink separations are presented. The equivalent selectivities for a wide-range of flotation reagents, relative to S-rejection, suggest that flotation is an efficient method for removing inorganic S but only when a substantially complete liberation can be achieved without excessive grinding. Attempts to reject particles containing included pyrites by the use of depressants or by more selective reagents do not appear promising. Yield-ash curves indicate that oily collectors, compared with frothing agents, give equivalent selectivities for some coals and improved results with others. The higher selectivities noted for the float-sink separation suggest that further work is required in the case of fine-coal cleaning based on gravity or accelerated gravity methods of separation. It is concluded that at the present time flotation processes afford the most practical solution.

Plant performance tests of the Tromp dense-medium coal-cleaning process M. R. Geer, M. Sokaski, and H. F. Yancey (*US Bur. Mines, Rept. Invest.* 5619, 1960, 1–34).

The relationships of the properties of coals with those of their cokes N. C. Sinha, B. K. Sinha, A. K. Roy Chowdhury, J. N. Sanyal, N. N. Das Gupta, and A. Lahiri (*Coke Gas*, 1960, **22**, Sept., 382–388) A statistical study comparing the coking values of some Indian coals with their physical properties, in which the difference in nature of Indian and Scottish coals, due to the generally higher mineral content of the former is stressed.—S.H.-S.

The design of coke-oven batteries for large coking plant M. Chocholáč (*Paliva*, 1960, **40**, (10), 306–311) A theoretical analysis is made of the factors determining the optimum number and size of coke ovens in batteries of large coking plants.—P.F.

Recent developments in British coal carbonization research G. W. Lee (*AIMME, preprint*, 1960, pp.27) A general review of the work of BCRA at the Coke Research Centre (21 refs).—C.V.

Carbonizing properties of Boone County, W. Va., coals D. E. Wolfson, G. W. Birge, and J. H. Lynch (*US Bur. Mines, Rept. Invest.* 5628, 1960, pp.14).

The Durgapur coking plant. Part II (*Coke Gas*, 1960, **22**, Aug., 337–342) An illustrated account of by-product recovery and of services and tar distribution.

Production of blast furnace coke from a blend using 75 per cent Illinois coal J. E. Oesterle (*AISI*, 1960, preprint, pp.10) The location of high volatile Illinois coal and low volatile eastern coal with low S- and ash-values was determined and a satisfactory 55:20:25 blend was achieved over a number of years; the coke is strong, of correct size, good surface characteristics, and low swelling pressure. Coke yield is 4–5% lower than with eastern coals on account of the high volatility of the Illinois coals. Experiments on the use of this local coal for blast-furnace coke are continuing.—C.V.

The running of coke-oven batteries in the Soviet Union B. Špichal (*Paliva*, 1960, **40**, (10), 311–314) Soviet coke-oven practice is surveyed on the basis of existing Soviet documentation and information obtained by the author from the lectures of, and in discussion with, Russian experts.—P.F.

Contribution to the refractory maintenance of Becker coke ovens Odile (*Centre Doc. Sid. Bull.*, 1960, (10), 2209–2212) The repair of regenerator walls of a coke oven by injecting refractory cement is described.—A.D.H.

Studies of coke-oven width, flue temperature, and coking rate J. B. Gayle and W. H. Eddy (*US Bur. Mines, Rept. Invest.* 5592, 1960, 1–35).—C.F.C.

Process of formation of coke and the forecasting of its quality E. Taits (**Koke Khim.*, 1958, (3), 19–25).

Production of metallurgical coke from hard coal G. Gruson (**Freiberger Forschungshefte*, 1957, **A69**, 55–57).

The national supply of metallurgical coke and the Moraes Rêgo Centre M. D. B. Latif (*Eng. Min. e Met.*, 1960, **31**, June, 324) A commentary on the last annual seminar held by the Centro Moraes Rêgo to discuss the supply of metallurgical coke is given and a plea made to develop a rational coal program in order to improve the supply of metallurgical coke which is indispensible to the industrialization of Brazil.—P.S.

Report on standardization of methods of testing coke quality L. I. Erkin (**Koke Khim.*, 1958, (8), 58–60).

The sampling of coke A. D. Denton and E. D. Tyte (*Coke Gas*, 1960, **22**, Oct., 435–437) The revision of BS.1017, Part II, is discussed.

Modern coke handling installation at Emden harbour K. Schmoll (*Austr. Mach. Prod. Eng.*, 1960, **13**, Nov., 13–15) The layout is designed to handle 780 yd³ of material/h (270 t coke and 480 t coal.)—C.V.

Improvements in iron production and their effect on coke requirements (*Gas World–Coking*, 1960, **152**, Oct. 1, 59–61) Movement away from the use of coke, particularly from good coals, is forecast.

Continuous benzole refining at Appleby-Frodingham Steel Company R. C. Dooley (*Coke Gas*, 1960, **22**, Sept., 403–409) The new APV continuous benzole distillation plant at Appleby-Frodingham is described and its equipment, operation, and products are discussed.—S.H.-S.

Gaseous reduction in steelmaking G. Lavoisier (*Europäischer Maschinen Markt.*, 1960, **10**, (5), 14–15) [In English] The economics of sheet-making in France in 1962–63 is discussed with a view to finding means of reducing the use of imported material. Recommendations are put forward, including fuel injection into tuyeres of blast-furnaces and the use of natural gas for direct production without coke.—R.P.

Conversions to gas firing A. Higgs and R. W. Deans (*Gas World*, 1960, **152**, Aug. 20; *Industr. Com. Gas*, **42**, (2), 28–30) Various examples are given; a slug heating furnace, ships' propeller floor moulds (25-t), lap-welding equipment, sand drying, ladle heating, a continuous Acme core-drying stove, a resin drum heating oven, a rivet-forging furnace and wool drying.—C.V.

AIR POLLUTION AND SMOKE

The fight against atmospheric pollution W. Seidl (*BWK*, 1960, **12**, Dec., 537–540) Results of work carried out by the VDI-Committee for Clean Air is discussed by various contributors with this aim in view.—R.P.

Mechanical dust collectors of low and medium efficiency R. Jackson (*BCURA, Monthly Bull.*, 1960, **24**, Aug.–Sept., 397–427) A very detailed review with 37 references. The plant is, in general, for use with boilers.—C.V.

Dust removal in arc furnaces W. Muhlrad (*Stahl Eisen*, 1961, **81**, Jan. 5, 41–46) The properties of the waste gases of arc furnaces make their purification extremely difficult, particularly if the furnace is run with oxygen addition. Good results have been reported with dry filter plants when filter bags made from synthetic fibre or fibreglass are used.

Dust removal from gases by means of Venturi tubes K. Doniec (*Hutnik*, 1960, **10**, (9), 346–351) Theoretical and experimental work relating to the design of efficient Venturi gas-cleaning plant, carried out in Poland, is described.—P.F.

Removal of dust from brown fumes in oxygen-blowing steelworks K. Guthmann (*International Clean Air Conference*, 1959, Oct., Preprint III, **26**, 62–64) The problem of removing dust from the brown fumes arising in the LD oxygen steelmaking process may be regarded as solved. In some cases a reasonable use of waste heat and precipitated dust may even make gas cleaning an economic proposition. Electrostatic precipitators were found to give the best results and the utilization of waste heat is considered a prerequisite for any economic method of dust removal. Examples are given of several arrangements of plant and the operational results therefrom.—C.F.C.

Technical removal of dust as dealt with by the European Coal and Steel Community High Authority, Luxembourg K. Guthmann (*International Clean Air Conference*, 1959, Oct., Preprint III, 27, 65) In 1958 the High Authority of the Coal and Steel Community, in agreement with the Special Ministers' Council, approved considerable grants in aid to assist in carrying out the four-year study in the field of dust removal in collieries, iron ore mines, and metallurgical industries. This paper is an outline of the program for this four-year study, under the following headings: technical removal of dust in mines with particular attention to combating silicosis, and technical removal of dust in the iron and steel industry, which latter is divided into applied and basic research.—C.F.C.

TEMPERATURE MEASUREMENT AND CONTROL

The metal-clad thermocouple J. A. Stevenson (*Platinum Met. Rev.*, 1960, **4**, Oct., 127–129) A new metal sheathed Pt–Pt–Rh with a Pt–Rh sheath (or a base metal design, or Pt–Au) is illustrated.

Precision of thermocouple equipment for temperature measurement (*Fonderie*, 1960, May, 204–206) Permissible and observed errors in NiCr–Ni and Pt–Pt-Rd couples are noted, causes of error listed and remedies suggested.

Wire temperature meter Addison Electric Co. Ltd and BISRA (*Metallurgia*, 1960, **62**, Aug., 64) A description of an instrument developed by the Addison Electric Co. Ltd, in collaboration with BISRA, for the rapid temp. measurement of moving wire. It has been calibrated over a speed range of 50–3000 ft/min, temp. of 50–300°C, and wire sizes of 9–16 swg, and is accurate to ±5°C.

REFRACTORY MATERIALS

The challenge of refractories research J. H. Chesters (*Trans. Brit. Ceram. Soc.*, 1960, **59**, July, 225–235) Personal experiences in research in industry are recounted pointing out that a problem that was solved 30 years ago may today be shown to have been based on false premises but that, by tomorrow, the whole position may again be reversed. A plea for a bold approach is made and it is suggested that calculated risks are worth while; if failure is met with, and there is no logical reason for it, another attempt should be made.—C.V.

Polish refractory clays studied under the electron microscope M. Grylicki, Y. Eysymontt, and J. Bryniarska (*Prace Inst. Hutn.*, 1960, **12**, (4), 199–205) A comparison of the clays examined with standard samples showed that the crystal structure of kaolinite from Opoczno clays is comparatively well defined while that from Jaroszow clays is not. Though expected, halloysite could not be detected and monothermite could not be identified positively.

Utilization of Bansi clay in the manufacture of refractories S. N. Seth, B. B. Bhatia, and K. H. Parikh (*Refract. J.*, 1960, **36**, Oct., 299–301) A clay deposit with 62% SiO_2, 32% Al_2O_3, and 2% loss on ignition might be suitable for fireclay brick production, taking steps to reduce porosity.

Studies of the possibilities of processing barytes into refractory barium silicates and aluminates M. Drylicki (*Prace Inst. Hutn.*, 1960, **12**, (4), 206–211) In the course of studies it was found that the production of barium orthosilicates may be difficult from the technological point of view owing to formation of easily fusible melts. The preparation of barium aluminate was found to be much easier. Production of celsian was also easy. During prolonged heating the hexagonal form was slowly transformed into the monoclinic.

Refractory compositions based on silicon–boron–oxygen reactions H. F. Rizzo, B. C. Weber, and M. A. Schwartz (*J. Am. Ceram. Soc.*, 1960, **43**, Oct., 497–504) The nature and properties of a novel refractory material formed by reaction silicon and boron in air are described. The resulting material consists of silicon and a new compound, SiB_4, dispersed in a borosilicate matrix. This refractory is stable in air to temp. exceeding 1550°C, is thermal-shock resistant, and has a low density.

Phase equilibria in the system iron oxide–Cr_2O_3–SiO_2 in air A. Muan and S. Somiya (*J. Am. Ceram. Soc.*, 1960, **43**, Oct., 531–541) Phase equilibrium data, obtained by the quenching technique, are presented for the liquidus temp. region of the system Fe_2O_3–Cr_2O_3–SiO_2 in air, which represents an O_2 isobaric section (pO_2=0·21 atm) through the quaternary system Fe–Cr–Si–O at a total pressure of 1 atm. The diagram is dominated by a large area of co-existence of two immiscible liquids, and high liquidus temp. prevail throughout most of the system. Possible applications to refractory problems are indicated.—S.H.-S.

The system iron oxide–TiO_2–SiO_2 in air J. B. MacChesney (*J. Am. Cer. Soc.*, 1960, **43**, Nov., 586–591) The phase relations of this system have been studied. The stable existence of the crystalline phases magnetite (ss), haematite (ss), pseudo-brookite (ss), rutile (ss), and silica (tridymite or cristobalite) in equilibrium with liquids in the system has been established and three isobaric eutectic situations are shown to be present. The liquid miscibility gaps present in the system iron oxide–SiO_2 and TiO_2–SiO_2 extend across the composition triangle representing the system iron oxide–TiO_2–SiO_2. Liquidus temp. within the two-liquid region decrease from ~1670° in the system iron oxide–SiO_2 and 1780° for the TiO_2–SiO_2 system; there is a min at 1540° in the central part of the miscibility gap where cristobalite and rutile (ss) coexist in equilibrium with the two liquid phases. Paths of equilibrium crystallization in air are shown simply in terms of a diagram projected on to the plane FeO.Fe_2O_3–TiO_2–SiO_2 and more completely with reference to the tetrahedron FeO–Fe_2O_3–TiO_2–SiO_2. Points representing the composition of liquids at liquidus temp. define an irregular curved surface, the 0·21 atm. O_2 isobaric liquidus surface, through the tetrahedron. Crystalline phases of variable composition are represented by points along their respective solid solution joins whereas the composition of SiO_2 is represented by the apex of the tetrahedron. Total composition of condensed phases vary along O-reaction lines, lines radiating from the O-apex of the tetrahedron representing the system Fe–Ti–Si–O.

Formation and structure of SiB_4 H. F. Rizzo and L. R. Bidwell (*J. Am. Ceram. Soc.*, 1960, **43**, Oct., 550–552) From analyses resulting from a study of observed and calculated interplanar spacings in SiB_4 it is suggested that the compound SiB_3 previously reported by Moissan and Stock is actually the compound SiB_4 with approximately one additional atom of Si per unit cell, i.e. Si_2B_{12}+Si.—S.H.-S.

Fire-bricks—corrosion phenomena in furnaces E. Steinhoff and H. Sachsse (*Corros. Techn.*, 1960, **7**, Sept., 290–291) A summary of a paper on the use of special bricks in the glass-making industry, given by Dr Steinhoff at the 77th Dechema Colloquium at Frankfurt in Feb. 1960, together with a report of the discussion contributed by Prof. Sachsse.

Facilities offered by research in the use of refractories in the iron and steel industry P. Paquin (*Rev. Mét.*, 1960, **57**, Nov., 1039–1041) Special reference is made to the activities of the Société française de Céramique and of the committees set up by it.

Refractories in the iron and steel industry A. Libon (*Rev. Mét.*, 1960, **57**, Nov., 1033–1038) Development and applications in recent years of refractories for blast-furnaces, Thomas, OH, and electric furnace plants, and reheating furnaces are reviewed, and possible improvements are examined.

Refractories usage at Gensett Iron Company Ltd C. Storey (*Refract. J.*, 1960, **36**, Aug., 238–240, 242) A general description. Blast-furnace

and OH maintenance are outlined with special reference to OH roof life. The soaking pits are also included.—C.V.

Basic refractories for open-hearth furnace checkers J. Hargreaves, J. R. Lakin, and J. Mackenzie (*Trans. Brit. Ceram. Soc.*, 1960, **59**, July, 260–283) Forsterite and magnesite bricks in the checkers are discussed. Specimens of the various bricks after 4–5 cycles at different temp. are shown and the various failures are examined. Plant trials are reported and illustrations are provided. The failure of the basic checkers under the conditions at Templeborough would appear to be physical rather than chemical. The best brick now in use is an Austrian magnesite which appears to be superior in both respects; the two effects may be associated. It is concluded that attention to the type, amount, and distribution of the matrix may result in a product immune from these factors and which, with regular cleaning, may give long life.—C.V.

Bond structure and behaviour of basic bricks at high temperatures H. M. Richardson, K. Fitchett, and M. Lister (*Trans. Brit. Ceram. Soc.*, 1960, **59**, Nov., 483–504) Direct bonding between magnesia and chrome grains is associated with good refractoriness-under-load behaviour at 1 600° and may give a decreased iron oxide bursting tendency; a lowered thermal shock resistance may also be developed. Volume stability at 1 800° may not differ markedly from that of a given brick at 1 700°. A direct bond between the magnesia and chrome in basic bricks has been formed by (*a*) heating commercial bricks at 1 800° (*b*) in a laboratory specimen fired at 1 700°, (*c*) in similar specimens fired at 1 600° with additions of fine chrome ore, titania, chromic oxide, or ferric oxide, and (*d*) when fired at 1 500° in the presence of fine chrome ore and titania.—C.V.

Some aspects of creep tests on refractories L. L. van Breukelen (*Chem. Weekb.*, 1960, **53**, Dec. 31, 742–747) This is a paper read on 15 May last before the Nederlandse Keramische Vereiniging reviewing the international methods of testing ceramics and pointing out the differences between them. To conclude, the author puts forward various proposals with the object of overcoming such differences and of bringing the methods into line.—F.R.H.

The apparent viscosity of refractory materials at high temperatures A. C. D. Chaklader, T. G. Carruthers, and A. L. Roberts (*Refract. J.*, 1960, **36**, Oct., 292–296) Silica glass and refractories, aluminosilicates, and basic refractories were examined in torsion at temp. up to 1 400°C.

Spalling of firebricks S. E. Wooley (*Refract. J.*, 1960, **26**, Oct., 313–314) A test method is described and preliminary comparisons with performance in service are made.

Development of furnace construction in East Germany M. Brieschke (*Neue Hütte*, 1960, **5**, Dec., 734–738) Problems connected with the establishment of a furnace construction division for the metallurgical industry of East Germany are considered, and the position in the manufacture of refractories and heat-resisting-rollers is examined.

IRON AND STEEL—GENERAL

Site testing for the Whyalla steelworks M. R. Knuckey (*BHP Tech. Bull.*, 1960, **4**, Nov., 2–7) A general description of the work undertaken, test bores, earth-bearing tests (static loading, footing size, moisture, shear and settlement, vibration) and pile tests. Tests on the ground water showed that SO_3 was present in high concentration and the effect on the available cements was studied.—C.V.

Presidential address: Steel in an expanding Britain Sir Charles Goodeve (*JISI*, 1961, **198**, June, 117–123) [This issue].

The German steel industry in 1960 J. Veuillot (*Usine Nouv.*, 1960, **16**, Special Issue, Oct., 17) This article describes a visit to German steelworks—Hoesch AG, Westfalenhütte, Krupp at Rheinhausen, and the Klocknev Group, giving details of production, capacity, and future development plans. It closes with a review of the prospects for the German steel industry within the European Coal and Steel Community.

Present and future aspects of Japanese iron and steel industry K. Takeda (*Suiyokwai-Shi*, 1958, **13**, Sept., 456–463) Here is a résumé of the outline of the present and future profile of the iron and steel industry in Japan. Reference is made to the transition in steel production in the past, the long-term production plan and the secondary modernization and expansion program. Technical developments concerned are further described.—B.S.F.C.

North-West China (*Met. Bull.*, 1960, Oct. 7, supplement i, iv) The sixth article of a series. Shansi, Shensi, Kansu, and Chinghai provinces and the Ninghsia-Hui autonomous region are briefly reviewed and coal and iron resources and steelworks are named.

China's iron and steel works. 8. South China (*Met. Bull.*, 1960, Nov. 22, i, iv) Iron- and steelworks in the four southern China provinces are covered, outputs being indicated. Some indication of the occurrence of other minerals, Cu, Mn, Sn, and coal, is also given.—C.V.

Cuba: Intervention in steel production (*Bull. ILAFA*, 1960, **1**, Oct., 11) The Cuban Government has intervened in the affairs of three steel companies, one of which, the Cia. Antillana di Acero, with two furnaces, is only operating one, supplied with Soviet oil. The production of steel and iron has been taken over by the Ministry of Economics, which will control all future developments.—S.H.-S.

Chile: Steel production. Increased output by the Cia. Electro-Metallurgica S.A. (*Bull. ILAFA*, 1960, **1**, Oct., 11–12) Various plans for increased production are reported.—S.H.-S.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Pig iron (*Bradley's Magazine*, 1960, Autum, 3–6) A brief review of production and composition.—C.V.

Production of sinter of high basicity and its use in the blast-furnace L. von Bogdandy (*Stahl Eisen*, 1961, **81**, Jan. 5, 12–22) The production of sinter with high levels of basic components, the properties of the sinter as a result of these and the effect of degree of basicity on blast-furnace practice are reviewed on the basis of published information. A comparison with theory is made of the results obtained in blast-furnace practice when using self-fluxing sinter and the peculiarities involved in the use of sinter with high basicity levels are reported (84 refs).—T.G.

Calculation of a blast-furnace G. Maggio (*Fonderia*, 1960, **9**, Oct., 445–449) A theoretical calculation is given of a blast-furnace which will produce 300 t of basic Bessemer iron a day.

Burden preparation and its effect on blast-furnace practice G. Heynert, P. Ischerbeck, and W. von Spee (*Stahl Eisen*, 1961, **81**, Jan. 5, 1–12) The new burden preparation plant including unloading equipment for ships and railway wagons, conveyors, crushers, a sintering plant, and other equipment built at the works Ruhrort of Phoenix-Rheinrohr AG is described and illustrated and the results obtained with a classified and sintered burden in the blast-furnace are reported. The improvement in the heat balance and the savings in coke justify fully the investment for the new burden preparation plant. Details of the savings are given.—T.G.

Thermodynamic and stoichiometric analysis of the blast-furnace process W. Kuczewski (*Preprint*, 1957, 1–30) Mathematical.—C.F.C.

Argentine steel production: site for a new blast furnace in Salta (*Bol. ILAFA*, 1960, **1**, Oct., 5) The Altos Hornos Guemes SA, with privately subscribed capital of 30 000 000 pesos, has bought 17 hectacres of land for a site for a new blast-furnace near Campo Santo in the Province of Salta, 35 kilos distant from its iron ore deposits. This site will draw gas from the Campo-Durán gas line and will also use high tension power from the Cosralito plant of the city of General Guemes.—S.H.-S.

Argentine steel production: Steel in Mar del Plata (*Bol. ILAFA*, 1960, **1**, Oct., 5) The IADARE Steel Co. plans to construct in Mar del Plata, Prov. of Buenos Aires, with the support of local capital, a steel plant for the exclusive production of building steel, making girders and beams of high grade steel for ferro-concrete construction.—S.H.-S.

The eighth blast-furnace of the Volta Redonda Steel Co. of Brazil (*Bol. ILAFA*, 1960, **1**, Oct., 7) The formal opening by the President of Brazil, J. Kubitschek of the eighth blast-furnace of the Volta Redonda Steel Co. on 10 Oct. 1960, is reported, with plans for increased production of ingot steel amounting to 1 300 000 tons per year total.—S.H.-S.

Enlargement of blast-furnace No.2 at Geneva Works L. Tofft (*AISI Preprint*, 1960, pp.27) The furnace enlargement and necessary changes to auxiliary equipment were completed in 140 days. The hearth dia. was increased from 25 to 26½ ft C-brick was used both in the hearth wall and in the tuyere and bosh regions; new hearth jackets were installed and nine existing furnace columns were re-replaced with longer columns, a new mantle section being installed at the top of the column. The furnace shell was raised so that the combination of longer column and new steel shell increased the furnace height by 12 ft. A new bustle pipe was installed at a higher elevation. The capacity of the skip cars was increased and the skip incline was lengthened. Facilities for high top pressure operation to the furnace were provided and the top section of the furnace downcomer and dustcatcher were reinforced to compensate for the top pressure. The three hot-blast stoves were increased by 40 ft, and larger and more efficient gas burners were provided. Height of the stove stack was increased by 35 ft as well as the elevator shell. Split-wind blowing facilities in the power house enabled more effective use to be made of the four turbo-blowers at the higher wind rates. The size of the furnace coke bins were increased and the volume to hearth area ratio was raised from 62·7 to 75·6. These enlargements and changes enabled the daily capacity to be raised from 1 300 to 1 532 t.

The history of the blast-furnaces in Kamaishi Iron and Steel Works in the last twenty years M. Saeki, J. Sawamura, and T. Fukuda (*Suiyokwai-Shi*, 1958, **13**, Sept., 464–467) Kamaishi is the place of origin of iron- and steelmaking in Japan. It is 100 years ago since the blast-furnace was built in Kamaishi. In this paper the authors report the history of the blast-furnaces at the Kamaishi Iron and Steel Works during the last 20 years.—B.S.F.C.

Smelting unfired iron ore pellets in an experimental blast-furnace N. B. Melcher and M. B. Royer (*US Bur. Mines, Rep. Invest.* 5640, 1960, 1–9) Preliminary trials of the addition of raw pellets of taconite concentrate to blast-furnace burden are described. Using 1% bentonite as binder relatively little loss in charging or as dust was found when unfired pellets were used.—C.R.C.

The influence of ore preparation on the results of blast-furnace operations R. Mintrop (*Tech. Mitt.*, 1960, Aug., 335–342) A report is given on recent improvements in pig iron production by efficient preparation of the charge. The method results in lower fuel consumption and increased output rates.—R.P.

Smelting experiments in the blast-furnace, using lime-treated coke P. Hüttemann and R. Mintrop (*Tech. Mitt.*, 1960, Aug., 356–363) The authors' short-term experiments show that pre-treatment of coke with lime does not result in worthwhile improvements unless the coking properties of the coal are poor.—R.P.

Trends and problems in blast-furnace research H. W. Hosking (*Austral. Eng.*, 1960, Aug., 48–53) A general review.—C.V.

Oil injected into blast-furnace Esso Research and Eng. Corp. (*Engineering*, 1960, **190**, Nov. 4, 599) If hydrocarbons, particularly heavy oil of high heat content, can be successfully injected into the bottom of a blast-furnace, it is considered that capacity can be increased and cost of hot metal production be decreased. This new fuelling system injects oil with heated air. It is noted that another approach is the injection of natural gas.—C.V.

Injecting solid fuels into smelting zone of an experimental blast-furnace E. J. Ostrowski, M. B. Royer, and L. J. Ropelewski (*US Bur. Mines, Rept. Invest.*, 5648, 1960, pp.14) Injection of anthracite fines replacing up to 28% of the coke in the burden is shown to be possible.

On the oxygen-enriched blast operation of the Higashida No.5 blast-furnace K. Tsujiahta,

K. Kodama, N. Tsuboi, K. Kato, and S. Hashimoto (*Tetsu to Hagane*, 1960, **46**, Aug., 955–961) A test period with increased O_2 and humidity in the blast showed increased iron production but no change in coke rate. The increase can be explained by an equation, which shows that 1% of oxygen enrichment is equivalent to a 4·76% increase in blast vol. The major improvement was decreased solution loss.

The use of steam in the Fontoy blast-furnace J. Laborne (*Centre Doc. Sid. Bull.*, 1960, (10), 2221–2238) The injection of 20 gm/m³ steam, into the blast increased the blast temp., increased the output, and decreased the coke consumption.—A.D.H.

The use of radioactive sources to study the wear of refractory linings G. Courtois and R. Hours (*Centre Doc. Sid. Tech.*, 1960, (10), 2239–2251) A review of the theory and practice of the applications of radioisotopes to measure refractory wear at elevated temp. with special reference to safety precautions.—A.D.H.

The influence of certain factors on the resistivity of the carbon lining of a blast-furnace J. Janowski and E. Mazanek (*Neue Hütte*, 1960, **5**, Dec., 743–752) Factors considered are: thermal expansion and conductivity of carbon material; the separate and simultaneous attack of pig iron and slag on the lining; the investigation of the action of slag and pig iron on rammed carbon; and the resistivity of the carbon materials used for the blast-furnace lining to attack by CO_2 (17 refs).

The Thibaut hot blast stove F. H. Thibaut (*Centre Doc. Sid. Bull.*, 1960, (10), 2213–2219) A new design of hot blast stove involving modifications to the design of the chequers and the provision of an external combustion chamber is described. The modification of existing stoves is possible in accordance with the new design.—A.D.H.

Acceptance and initial operation of blast-furnace-gas conduit, ϕ 1200 and 1400 mm, 2·5 Km long T. Kuratow (*Hutnik*, 1960, **27**, (9), 345–348) The duct was delivered in sections (longest 2260) and for most part erected suspended on iron supports; the supports also carrying other services. There were no Polish standards so special tests were evolved and are given in the article.

The low-shaft furnace considered as a small experimental blast-furnace E. Bonnaure (*IRSIA, IWONL, Compt. Rend. Recherches*, 1959, July, pp.70) Research carried out in 1958 enabled the low-shaft furnace to be considered as a small experimental blast-furnace. The writer emphasizes the decisive factors of counter-pressure, rapidity, and the granulometry of materials. Interesting experiments have been carried out with the fuel oxygen and steam. A complete program of investigations in the blast-furnaces is given which provides valuable information for fundamental study of the physical chemistry of blast-furnaces.

The Companhia Vale Do Rio Doce: Important plant to benefit the national economy (*Eng. Min. e Met.*, 1960, **31**, May, 229, 231) In addition to the plan to export 20×10^6 t of ore, the Company is to instal plant in Itabira for the manufacture of sponge-iron and fine steels. Details are given.—P.S.

The Vatú Iron Company C. F. de Moraes (*Eng. Min. e Met.*, 1960, **32**, July, 33–40) [In Portuguese] Details are given of the sponge-iron plant to be built. The Hoganas process has been chosen and the Campestre ore fines will be used. An immediate program for the production of 50000 t/year is planned; the final stage will reach a capacity of 150000 t. This account is followed by a brief review of uses of sponge iron in industry.—P.S.

Alternatives to the blast-furnace J. M. Ridgion (*Swansea Met. Soc. Advance Copy*, 1959, pp.1–20) A review in general terms of nine alternative processes with some comparative figures.

HyL sponge iron production J. Celada, G. H. Muller, and E. W. Riblett (*Chem. Eng. Prog.*, 1960, **56**, Sept., 66–70) A description of operations and processes at the Hojalata y Lamina works at Monterrey.—C.V.

Report on manufacture of sponge iron in Japanese special native furnaces (Kaku-Gama and Nobori-Gama) during the last Great War (II), (IV), (V), (VI), (VII) H. Sawamura (*Suiyokwai-Shi*, 1954, **12**, (5), 213–218; July, 307–312; 1955, **12**, March, 417–424; Nov., 35–38) Sponge iron was manufactured during Great War II in Kaku-Gama and Nobori-Gama, Japanese special native furnaces which had been used for the manufacture of porcelain vessels. This paper is a report of the results of an investigation of the above mentioned method which was carried out at the Mikado Works of the Toatokushuseiko and Co. in Chiba prefecture and at the Obori Works and the Kodaka Works of the Somajukogyo and Co. in Fukushima prefecture by the sub-committee of the seventh committee of the Japan Science Promotion Society.

Fundamental researches on sulphuric acid process ashes as pig-iron making material T. Aakimoto and S. Onishi (*Suiyokawa-Shi*, 1955, **12**, June, 513–518) To clarify the differences in the reducing behaviours according to the composition, the cinders were investigated from the following points of view: (1) reduction efficiency in the reaction of CO gas and pitch cokes, (2) measurement of the permeability (AFA) at various temp., (3) compared with the surface conditions of grains by electron microscopical examination, (4) measurement of the surface area by the BET process.—C.F.C.

Producing nickel-bearing iron from Cuban ores in a batch rotary kiln W. M. Mahan (*US Bur. Mines, Rept. Invest.* 5638, 1960, pp.21) Production of iron with 3–7%Ni as sponge is reported. The Krupp-Renn process was unsuitable.

Sickles from the sand M. R. Gardi (*Lloyd's Register of Shipping, Bull.* 100 Al, 1959, (4), 32–35) A method of iron smelting in the N. Cameroons of W. Africa is described.

PROPERTIES, TREATMENT AND USE OF SLAGS

Experimental determination of the properties of ironworks slag W. Kayser (*Tech. Mitt.*, 1960, Aug., 364–370) The author describes experiments on 11 different slags and discusses results obtained as a means of deciding on the quality of the material. Determinations of open, closed, and total pore volume, drop-shatter tests, and abrasion resistance are dealt with in detail.—R.P.

Studies on high-titanium slags (1st report) H. Nishimura, I. Kushima, J. Moriyama, O. Senda, and K. Kawano (*Suiyokwai-Shi*, 1955, **12**, March, 433–436) Specimens corresponding to the systems $(FeO–TiO_2)$–(TiO_2), $(FeO.TiO_2)$–$(MgO.2TiO)$ were synthetically prepared by arc melting in an A atmosphere. These specimens were heated by a W-wire coil in A and their melting points were measured with an optical pyrometer. The emissivity coefficients of these slags were found to be between 0·7 to 0·8. From the measurement of the melting points, it was found that there exists a compound $FeO.2TiO_2$ whose melting point was 1610°C, and two eutectic points corresponding to $(FeO.TiO_2)$–TiO_2. The melting points in the system $(FeO.TiO_2)$–$(MgO.2TiO_2)$ changed from $(FeO.TiO_2)$ to $(MgO.2TiO_2)$ continuously.

Activities of iron oxides in FeO–Fe_2O_3–CaO–SiO_2 system and equilibrium oxygen pressures of O_2–slag–liquid iron system A. Yoshida (*Nippon Kinzoku*, 1960, **24**, Jan., 50–54) Formulae for the activities of FeO, Fe_2O_3, and total FeO are derived, and the activities are calculated numerically for oxygen pressures in the range 10^{-10}–1 atm (10 refs).—K.E.J.

Use of heat from slag A. Devigault (*Tech. Mod.*, 1960, **2**, Sept., 450–451) The writer reporting on a recent development in the USSR describes a method of heat recovery from slag for the production of electricity by using G. Claude-Boucherot's cycle. The idea is original but difficult to put into practice on an industrial scale.

Chile: Production of cement with blast-furnace slag (*Bol. ILAFA*, 1960, **1**, Oct., 12) The Co. Cementos Bio–Bio SA plans construction of a cement plant in the Province of Concepcion to utilize slag proceeding from the Huachipato blast-furnaces of the Cia. de Acero del Pacifico Koppers International (subsidiary of Koppers Co. of Pittsburgh), Transoceanic AOFC, and the Corporation of International Finance (IFC) are participating in financial support, in association with native Chilean capitalists.—S.H.-S.

PRODUCTION OF STEEL

The Itabira Special Steels Company (Acesita) (*Eng. Min. e Met.*, 1960, **31**, June, 303–304) [In Portuguese] A brief account of the development of this Company, the Cia. Aços Especiais Itabira, is given. Nearly 40000 t were produced in 1959, of which about 86% was in special steels. The program of investment, technical expansion, social provision, and reafforestation is indicated.—P.S.

The first stone has been laid at Taranto—Finsider's fourth steelworks (*Fonderia*, 1960, **9**, Sept., 423–424) A description is given of the plant and capacity to be installed.

Venezuela: Progress in the construction of the Orinoco steel plant (*Bol. ILAFA*, 1960, **1**, Oct., 15) Progress on the construction of the new steelplant being erected in the State of Bolivar, 500 km from Caracas, on the right bank of the Orinoco River, is reported in some detail.—S.H.-S.

Steel consu in the State of Minas Gerses, Brazil (*Bol. ILAFA*, 1960, **1**, Oct., 7) A census of all steel plants in the State of Minas Gerses, either in production or in course of construction is reported to be in progress.

Some of the recent steel products T. Mine (*Tetsu to Hagane*, 1960, **46**, Aug., 1010–1023) [In Japanese].—K.E.J.

The problem of quality of lime as applied in the basic steel process K. Radzwieki, Z. Kulinski, and B. Paczula (*Hutnik*, 1960, **27**, (7–8) 283–286) The authors point out that sulphur is frequently introduced into the lime from the fuel used in the lime kiln. In consequence a fuel having a low sulphur content should be used in the burning of lime. It was found that by using purified or natural gas, sulphur content could be reduced below 0·005%.

New metallurgical possibilities arising from the reactions obtained by the injection of powdered materials into liquid metals M. Allard (*Rev. Mét.*, 1960, **57**, Nov., 985–989) Methods adopted for increasing slag-metal reaction speeds by injecting powders are reviewed.

Breaking iron castings by high explosives H. H. Collins and A. D. Lamb (*BCIRA J.*, 1960, **8**, Sept., 717–725) Cast iron responds well to the technique of breaking by explosives and charges required are very much smaller than those necessary for equivalent sections of steel. Although the use of high explosives in the fragmentation of castings is well established in some parts of the ironfounding industry, it seems possible that the technique may be suitable for much wider use than at present. BCIRA has investigated methods of breaking castings, particularly to obtain samples for examination from castings which would have been difficult to break up or cut by conventional techniques. Regulations covering the purchase, storage, transport, and use of explosives are outlined, and the equipment and techniques used by BCIRA are described. Examples of castings broken in this way are given and illustrated. Those interested in using explosives for breaking castings are strongly recommended to seek the advice of the manufacturers of the explosives.—S.H.-S.

Maintenance in the steel plant: Results of planned maintenance repairs R. R. Kenny (*Iron Steel Eng.*, 1960, **37**, Sept., 144–146) A description of the use of plastic castable refractories in planned maintenance repair work at the works of Ford Motor Co., Dearborn, Michigan.

The physical chemistry of oxygen steelmaking D. L. McBride (*J. Met.*, 1960, **12**, July, 531–537) The chemical and thermal aspects of basic oxygen steelmaking are discussed and compared with those of other processes (18 refs).

The deoxidation equilibrium of titanium in liquid steel J. Chipman (*Trans. Met. Soc. AIME*, 1960, **218**, Aug., 767–768) A brief mathematical study.—S.H.-S.

Intensified steel smelting in furnaces F. P. Edneral (*Stal'*, 1960, (11), 1004–1007) An account of a conference in Moscow, 24–27 May 1960, with brief abstracts of the papers.

The conference issued recommendations which are given.

Recent developments in oxygen steelmaking A. Jackson (*Rail. Steel Topics*, 1959, **5**, Autumn, 40–47) New developments in the evolution of the traditional bulk steelmaking processes, with especial reference to the use of tonnage oxygen are described, including modifications to the bessemer process, the LD or Basic Oxygen process, the Graef Rotor process, the OH furnace, and the Ajax process (as used at the Appleby-Frodingham works of the United Steel Companies) with a brief summary of results.—S.H.-S.

Symposium on basic oxygen furnaces: equipment layout S. Vajda (*Iron Steel Eng.*, 1960, **37**, Oct., 73–78) A description of the general layout, and of handling, charging, teeming, and cleaning systems at LD plants in the USA.

Developments in acid Bessemer steelmaking A. B. Wilder (*Blast Furn. Steel Plant*, 1960, **48**, July, 679–689) Deals with instrumentation, nature of fume, low P steel for seamless tubes, free machining steels, including leaded steels, high-C steel strapping, buttwelded and seamless steel tubes, low-N_2 steel, and steel embrittlement.

Symposium on basic oxygen furnaces: vessel and lance design J. Reichmayr (*Iron Steel Eng.*, 1960, **37**, Oct., 78–81) The development of optimum vessel shape and O_2 lance design for the LD process is described. Economic limits of yield and refractory wear are limiting factors.

Segregation of phosphate slags in the converter G. Mahn (*VDIZ*, 1960, **102**, Oct., 1328) By adjusting the CaO additions in 30-t basic Bessemer converter blows, sufficiently high P_2O_5 contents were obtained to obtain a separation of the slag into two phases at the end of the blow. The composition of the phases was investigated.

The technology of steelmaking from Kachkanar vanadium iron is improved A. L. Klein, A. I. Pastukhov, A. N. Lokontsev, G. S. Kalganov, and Yu. A. Kharitonov (*Stal'*, 1960, (12), 1081–1086) Top blowing with O_2 in a converter and addition of scale or concentrate or even water to lower the temperature is used. A modified tapping hole improves slag recovery.

The service life of refractories in ferrous metallurgy converters A. N. Gaodu (*Ogneupory*, 1960, (9), 405–410) The decisive factor determining the life of converter linings melting low-carbon Fe–Cr is the composition of the original metal, and especially its silicon content. It is advisable to increase the thickness of the linings in the tuyered zone with more resistant refractories, for example, with calcined magnesite, with the rest of the linings of periclase-spinel bricks. Intermediate repairs should be carried out periodically.

Blowing methods in steelmaking G. Yocom and L. Xidis (*Iron Steel Eng.*, 1960, **37**, Sept., 101–109) An outline and comparison are given of the main features of the acid and basic Bessemer, basic top-blown oxygen, and Kaldo processes, and a note is given of modifications developed.

Oxygen converter processes H. F. Padbury (*Refract. J.*, 1960, **36**, June, 170–172) Discussion on the paper published previously (*ibid.*, May).

Desulphurization and deoxidation of steels by injection S. L. Gertsman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res. & Special Proj. Rept.*, 1960, Jan. 15, 13–14) Preliminary work has shown large reductions in S by injection of CaO and Mg. Ca–Mg alloys will be tested.

Tests on Bessemer bottoms made from Neau dolomite J. de Hedouville (*Centre Doc. Sid. Circ.*, 1960, (9), 1947–1952; discussion 1952–1954) Details of the manufacture, properties, and service life of ten basic Bessemer bottoms made from Neau (French) dolomite are given. Their life is at least equal to that of the normal bottom made from Belgian dolomite.—A.D.H.

Nitrogen in the Thomas converter J. Galey (*Centre Doc. Sid. Circ.*, 1960, (9), 1955–1961; discussion 1961–1964) The determination of the nitrogen content of metal during the course of a basic Bessemer blow showed that it reached a minimum value when Si was eliminated. The nitrogen content increased rapidly during the subsequent blowing period and the final content was 60–80% of the minimum value. The addition of limestone and ore in the middle of the carbon blow reduced the final N_2 content.—A.D.H.

Bottom blowing with oxygen G. Savard, R. Lee, and M. R. Campbell (*J. Met.*, 1960, **12**, July, 566–569) In the iron refining process developed by Canadian Liquid Air Co. in conjunction with Dominion Iron and Steel Corp., Nova Scotia, high-pressure O_2 is injected into the bottom of the metal bath through specially designed injectors, the cooling effect of the O_2 flow obviating the need for an external coolant. The results of pilot-plant trials are reported.

The place of basic oxygen steelmaking A. B. Wilder (*J. Met.*, 1960, **12**, July, 529–530) The reasons for the increasing use of basic oxygen process, particularly the LD process, are outlined.

An efficient conversion process for irons smelted from Kerch ores S. I. Lebedeba, A. V. Rudneva, and A. E. Khlebnikov (*Izvest. Akad. Nauk, Otdel. Tekhn., Met. Toplivo*, 1960, (4), 85–94) The conversion method for these irons worked out by the Baikov Metallurgical Institute proceeds in two stages: A low temp. air blast to remove the V and Si from the iron with the production of conversion V slags containing 5–6%V_2O_5 and then a high temp. blow with O_2 of the unfinished product containing 3–3·5%C and 1·8–2%P, with the production of high-phosphorus slags and steel of the given composition. Tests for the second stage have not been successful without prior preparation of the ore and the lime and this publication deals with this point, i.e. the preparation of the Kerch ores and the lime before smelting.

Great Lakes Steel Corp. announces LD steelmaking plant (*Iron Steel Eng.*, 1960, **37**, Sept., 206) A description of the proposed layout of the basic oxygen steelmaking shop at this Detroit subsidiary of National Steel Corp.

LD—in the beginning F. W. Starratt (*J. Met.*, 1960, **12**, July, 528–529) The early development of the LD process, and its economic and technical background are described, with particular reference to the experiments carried out in the immediate post-war period in Switzerland by Professor Dürrer.

New developments in LD steelmaking H. A. Trenkler (*J. Met.*, 1960, **12**, July, 538–541) The use in LD plants of ore cooling and of high-P hot metal, and the production of high-C and low-alloy steels are described (10 refs).

Factors limiting the oxidation of carbon in liquid iron E. Dun and S. I. Filippov (*Izvest. VUZ Chern. Met.*, 1960, (1), 16–23) In a special laboratory apparatus the action of factors such as the composition of the blast and its effect on the rate of decarburization of the metal has been studied; the ratio between the rate of oxidation of the carbon and that of the supply of oxidizer to the bath; the dependence of the rate of decarburization of the metal and the weight of the metallic bath; the carbon content in the metal with different compositions of the bath, and the rate of decarburization etc.

The processes in the oxidizing melt of steel in the rotary laboratory furnace S. I. Filippov, T. Zh. Arystynbaev, and G. S. Surovtsev (*Izvest. VUZ Chern. Met.*, 1960, (2), 10–14) A special laboratory 60 kW, 200 kg/s rotary furnace is described. It rotates on a horizontal axis through an angle of 90°. The magnesite refractory crucible was rammed into a special metallic frame which remained with the crucible. Its service life extended to 5–7 melts of 2 kg each. Metal temp. were measured with Pt–Pt-Rh thermocouples. Technically pure oxygen was the oxidizer. The experimental results can be explained by extending the theory of kinetic oxidation of mixtures of fused metals. Up to a critical concentration of the additions to the metal, the process proceeds by diffusion and the rate of reaction is determined by the penetration of the oxidizer into the zone of reaction. Below this critical concentration the process slows down considerably.

Oxygen in steelmaking W. H. Dennis (*Min. Mag.*, 1960, **103**, Oct., 201–205) A brief review of the LD, Kaldo, and Rotor processes.—C.V.

Pneumatic processes of converting high-phosphorus iron P. Coheur (*Iron Coal Trades Rev.*, 1960, **181**, Nov. 11, 1049–1054) Conventional bottom blowing with air is still used. The use of O_2-enriched air or O_2-steam is increasingly found. The LD and LD–AC processes are discussed; these give an equivalent quality of steel to that obtained with the O_2+H_2O or open-hearth methods.—C.V.

Smoke formation in Bessemer converters (*Batelle Tech. Rev.*, 1960, **9**, Nov., 2) A 2-lb laboratory scale converter is used to study the evolution of gases, their nature, and their control.—C.V.

The use of Renn pellets in the basic Bessemer process H. G. Bansen (*Tech. Mitt.*, 1960, Aug., 343–355) Experimental evidence is given, showing that the use of pellets (up to 10% of the charge) requires less coke, limestone, and blast than conventional charges. The furnace capacity is increased by the method described (20 refs).—R.P.

The VLN steel making process R. W. Evans (*Iron Coal Trades Rev.*, 1960, **181**, Dec. 16, 1325–1326) The use of the steam–O_2 converter process results in a much lower nitrogen content; thus it has been called the Very Low Nitrogen (VLN) process. A weekly production of 19 000 t is aimed at.—C.V.

On the surface blow converter process with pure oxygen Y. Shiga (*Suiyokwai-Shi*, 1955, **12**, June, 523–528) The surface blow converter process with pure oxygen was developed at the two steelplants, Linz and Donawitz, in Austria during 1952 and 1953 with remarkable success. Consequently the qualities of converter steel have been greatly improved. In this article the author gives the outline of this new steelmaking process and discusses several problems which should be considered when this process is applied in Japan.

Application of the LD process to high-phosphorus iron A. Bruno (*Iron Coal Trades Rev.*, 1960, **181**, Dec. 2, 1219–1224) It was initially considered that this material could not be treated by the LD process, but the results obtained at Pompey show that OH steel can be produced at quite an economic figure with complete use of the materials consumed. Uncrushed lime is used and fluxes are absent. Elsewhere it is reported that with a 60-t converter a very large output has been achieved.—C.V.

The steel-making plant at Durgapur—The story of the melting shop (*Sci. Eng.*, 1960, **13**, July–Aug., 101–105) A general description of layout and equipment.

Chemico-physical elements in the production of steel. Part II G. Violi (*Met. Ital.*, 1960, **42**, Oct., 263–277) Part II deals first with the chemico-physics of slags, then with the distribution of oxygen between slag and iron in the absence of carbon and the decarburizing reaction.

Considerations on design and operation of open-hearth furnaces M. Hansen (*Stahl Eisen*, 1961, **81**, Jan. 5, 51) A letter. The author presents some numerical calculations based on deductions made by F. Bartu (*ibid.*, 1960, **80**, 1268). The results are discussed with reference to the operation of OH furnaces.—T.C.

Ideal operating conditions for basic open hearth furnace roofs I. P. Bas'yas, T. A. Vyaznikova, V. D. Koksharov, E. I. Dikshtein, I. A. Selivanov, A. R. Makarychev, and K. S. Nazarov (*Stal'*, 1960, (12), 1086–1092) Factors affecting the wear of magnesite–chrome roof components are considered. Rates of heating, furnace atmospheres, and temperatures are discussed and the best operating conditions are worked out. Conditions bringing about the breakdown of roofs are especially reviewed.

Combustion control of open-hearth furnaces D. Meachen (*Process Control Autom.*, 1960, **7**, Oct., 494) A summary of BISRA Report *SM/AH/123/59*.

Oil firing of reconstructed open-hearth furnaces L. Kodrle and O. Pavlik (*Hutník*, 1960, **10**, (9), 339–346) Principles employed in the conversion of a 140-t tilting and a 120-t fixed furnace from gas to oil firing are discussed, and the performance of the furnaces before and after conversion is considered.

Examination of the flames of the OH

furnaces at the Magnitogorsk Metallurgical Combine N. I. Kokarev and V. G. Lisienko (*Izvest. VUZ Chern. Met.*, 1960, (2), 175–181) The flames were cinematographed, thus allowing a full study of their structure. It has been established, in particular, that both the gas and the pitch flames consist of separate large eddies between which the combustion of the fuel takes place.

Relation between the actual and the equilibrium concentration of hydrogen in steel in the course of the OH furnace melts K. T. Kurochkin, B. A. Baum, and R. P. Kostyuchenko (*Izvest. VUZ Chern. Met.*, 1960, (2), 25–31) The concentration of H_2 in steel samples drawn during the course of the melt starting with the melt-down, grows uniformly; reaching its maximum before deoxidation. The actual H_2 concentration in the liquid steel in small OH furnaces is below the equilibrium concentration in all the periods of the melt.

Distribution of sulphur between metal and slag during the boil in the production of low manganese conversion iron P. N. Perchatkin, A. S. Panov, A. A. Bezdenezhnykh, A. M. Bigeev, V. N. Letimin, and A. I. D'yakonov (*Izvest. VUZ Chern. Met.*, 1960, (1), 33–40) In the production of OH low-Mn conversion iron, slags with high silica content form during the melting period, though one of the important methods of desulphurization is the reduction of silica content in the slag. The desulphurization potential of the slag during the melting period increases with an increase in the concentration of ferrous oxide. The desulphurization is due to the redistribution of the iron sulphides between metal and slag. In the acid slags of the melting period, containing over 33·5%SiO_2, the coefficient of sulphur distribution is independent of the other components.

The pattern of nitrogen absorption by the metal during the oxidizing melt E. Dun and S. I. Filippov (*Izvest. VUZ Chern. Met.*, 1960, (1), 28–32) Experimental melts were carried out with a nitrogen content in the blast of between 96 and 60% with a 60% coefficient of oxidizer used. This corresponds to partial N_2 pressures of 0·938 and 0·484 atm respectively. Results are given graphically under such headings as the variations of the N_2 content in the metal during the oxidizing melt with different proportions, of N_2 in the blast and at different temp.; the saturation of the metal with N_2 as a function of the carbon content in the metal; the solubility of N_2 in the metal as a function of its partial pressure etc.

Affecting the oxygen level of soft (mild) open-hearth steels during their production. II W. Hess (*Stahl Eisen*, 1961, **81**, Jan. 19, 103–110) The effect of O_2 on steel in theory and in practice is discussed and the causes of oxygen pick-up during tapping are considered. Sample taking is described. The application of the theoretical deductions and of the results obtained in various trials showed that an inclusion-free, soft, rimming steel of good rolling qualities can be produced by appropriate additions of silicon-free, high-carbon pig iron or aluminium.—T.G.

Preliminary investigations into pig-iron oxidation in the basic converter with side blast K. Radzwicki, J. Natkaniec, K. Oracki, and S. Tochowicz (*Hutnik*, 1960, **27**, (4), 137–141) The authors first deal with the advantages of this process and then describe their experimental converter and its operation. The authors conclude that though their results were of no great immediate significance they point to a profitable field of investigation.

The effect of the difference in limestone type on the course of refining in the basic Bessemer converter W. Köhler, J. Schoop, G. Trömel, and K. H. Obst (*Stahl Eisen*, 1960, **80**, Nov. 10, 1689–1695) The continuous monitoring of the refining process in a basic Bessemer converter showed, when using limestone of different origins, degree of calcination and lump size, that the lime exercises a far greater effect on the dephosphorization than has hitherto been assumed. The results obtained in a production converter are presented in many graphs and tables.—T.G.

The dephosphorization process in the basic Bessemer converter with special reference to low phosphoric acid and high lime contents in the slag K. G. Speith, H. vom Ende, and G. Mahn (*Stahl Eisen*, 1960, **80**, Nov. 24, 1759–1770) The theory of the dephosphorization process is discussed with special reference to the correlation between (Fe) and (P_2O_5) contents of the slag, as well as the [P] level of the melt. Results of trials with lime-saturated slags in a 40-t converter are reported and interpreted in terms of the ternary equilibrium diagram FeO–CaO–P_2O_5. The corresponding oxygen contents of the steel in the presence of phosphate slags are considered. These results are compared with those obtained in the laboratory. The report is followed by a lengthy, very interesting discussion (29 refs).—T.G.

New developments boost quality of acid-Bessemer steels A. B. Wilder (*Iron Age*, 1960, **185**, June 23, 110–112) A review of development, operation, and theory.

The refining of basic Bessemer pig iron by the oxygen process E. Plöckinger, M. Wahlster, K. Borowski, J. Maatsch, A. Schildkötter, and V. Schiel (*Stahl Eisen*, 1960, **80**, Oct. 27, 1477–1486) The theory of oxygen blowing is discussed and the results of a study of the reactions taking place in the liquid and gas phases during blowing are reported. It was found that the most favourable conditions for refining and particularly for dephosphorization exist when the refining gas is a mixture of O, CO_2, and CO at about 2800°C. Refining is best achieved in two stages, in the first a phosphate slag low in iron is obtained, and in the second, a steel that is equal, or even superior, to OH steel. The slag from the second stage can be re-used. Trials in a 60-t converter were successful; lance distance and oxygen pressure were kept constant, making the work of the generator much easier (22 refs).—T.G.

Bessemer process updated with steam–oxygen blowing G. M. Yocom (*Steel*, 1960, **147**, Aug. 22, 82, 85) The use of a mixture of steam and oxygen for the production of better steel at the Wheeling Steel Corp's. Steubenville, Ohio, plant in Bessemer converters is claimed to make steels comparable to OH grades. The process is briefly described.—S.H.-S.

Oxygen in the steel industry with special reference to the production of steel by the L.D process F. Krupp (*Calore*, 1960, **31**, Sept., 471–498) This article describes the historical development of the method and its application to the various steelmaking processes, in eliminating defects in semi-finished and finished steel and the layout of oxygen plants in general. A detailed description is given of their design, construction, and operation at the works of Voest, at Linz, Austria.

Steelmaking by injection of oxygen and lime powder Irsid–O.L.P. process B. Trentini and M. Allard (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 186–190) The technology and metallurgy of the O.L.P. process are outlined and the properties of the steel produced are given.

Refining of Indian pig iron in an experimental L–D oxygen converter (I) D. L. Sen, B. R. Nijhawan, and A. B. Chatterjea (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 192–199) The origin and underlying principles of the LD process are outlined briefly, the reactions taking place and the properties of the product are described, and an account is given of the O_2-powdered lime injection process for refining phosphoric irons. A double slag technique has been used in small-scale trials in the National Metallurgical Laboratory, on irons containing 1·5–2·0%Si, 0·7–1·0%Mn, and 0·35–0·4%P. **(II)** B. L. Sen (200–210) The technical and economic possibilities of the LD process in the light of Indian conditions are discussed, and compared with the OH and basic Bessemer processes. The suitability of a 1·5%Si iron with a medium P content for refining in LD converters is demonstrated, provided that a double-slag treatment is applied. The use of the LD converter as a prerefining unit is also considered.

On the bottom blown processes and the LD–AC process P. Coheur (*Symposium on Iron and Steel Industry in India*, 1959, Feb., 212–221) The first part of this report deals with the development in bottom blown processes, basic and acid, with particular reference to the use of O_2. In the second part of the report, the LD–AC process is described briefly, and results obtained are discussed.

Dust removal from the brown fumes of a Bessemer converter with a wet electrofilter K. Guthmann (*Stahl Eisen*, 1960, **80**, Nov. 24, 1803–1805) A dust removal plant incorporating a wet electrofilter is described which is specially designed for small converters. The usual plants for dust removal which are combined with waste-gas boilers are much too complex and expensive and therefore not an economic proposition for small converters as, for instance, those of 2·7 t capacity. The plant described is laid out for 32000 m^3/h and is fully automatic. The dust content of the cleaned gas was 40 mg/m^3 at 40°C.—T.G.

Electronic scale systems weigh open hearth charge Inland Steel Co. (*Steel*, 1960, **146**, June 13, 164–166) The use of strain-gauges for weighing the charge for OH furnaces is described. Hot metal ladles are weighed at one station. Cars holding charging boxes are weighed as they pass over another section of track at 1½ mph. The system is reported to require the minimum of excavation and to be accurate and trouble-free.—D.L.C.P.

Utilization of the reserve capacity of existing open hearth furnaces M. B. Zil'bershtein, P. K. Morokov, and V. N. Kazantsev (*Stal'*, 1960, (11), 984–988) Alterations to existing furnaces to increase capacity and output are described. Increase of volume without much change of bottom design made the upper fittings unsuitable, and changes in these such as increased stack height, better roof refractories, better arrangements for dust and deposits removal and enlargement of slag pockets and regenerators were carried out. Methods of repair and fettling were also improved.

The use of furnaces with highly refractory basic roofs to improve the quality of chromium steel I. A. Andreev, L. Ya. Gluskin, V. D. Litvinov, V. A. Kovachich, I. A. Frumkin, Ya. I. Moshchuk, V. I. Dolbilkin, P. A. Romanov, and A. B. Boiko (*Stal'*, 1960, (10), 896–898) Steel with 3·5%Cr and 0·1–0·15%C could only be produced when the silica roofs were replaced with magnesite–chrome. Other measures to eliminate inclusions and improve mechanical properties are taken.

Spring suspension cuts roof brick wear Geo. P. Reintjes Co. (*Steel*, 1960, **146**, June 6, 106–108) An OH roof installation is described, which allowed the furnace to run for 306 heats. The design uses burned magnesite chrome metal-encased bricks hung from a steel framework that is supported by a coil spring system. The lifting mechanism is designed to eliminate excessive pressure in the arch structure.

The life of forsterite bricks in open-hearth regenerators A. V. Leskov and G. A. Molotkov (*Ogneupory*, 1955, **20**, 243 ff; *SLA* 60–13961; from *US Tech. Trans.*, 1960, **3**, June 24, 799) No abstract.—S.H.-S.

The technology, state and quality of magnesite–chromite roof bricks M. P. Nazarov, N. N. Kirillova, and Yu. V. Radina (*Ogneupory*, 1958, **23**, (10), 454–461; *SLA* 60–13977; from *US Tech. Trans.*, 1960, **3**, June 24, 799) No abstract.—S.H.-S.

Combustion of fuel oil and natural gas in open-hearth furnaces A. G. Trifonov, Yu. B. Snegirev, and E. V. Val'piter (*Metallurg*, 1960, (10), 14–19) A new method of burning fuel oil and natural gas by using a three-stream Venturi-type port and by feeding the fuel into the end of the block has been successfully introduced at the Magnitogorsk combine.

Application of the LD process to high-phosphorus pig irons. Technique used at the Pompey steelworks G. Messin (*Rev. Mét.*, 1960, **57**, Oct., 947–954) Details are given of the procedure, which is a two-slag process, using ore and scrap as cooling agents, and introducing the lime and ore during blowing (15 refs).

LD steel from high-phosphorus iron G. Messin, L. Lambert, and G. Helfenstein (*J. Met.*, 1960, **12**, July, 542–544) Development work carried out by Aciéries de Pompey is described, leading to the production of quality steels by the LD process, irrespective of P or Si contents.

Pneumatic processes for converting high-phosphorus iron P. Coheur (*J. Met.*, 1960, **12**,

July, 545–547) Recent information on European developments, with special reference to the LD–AC process.

Notes on Algoma's LD steel plant. 1. Low to high carbon steels C. C. Benton (*J. Met.*, 1960, **12,** July, 548–550) Operating data are given for manufacturing 0·03 to ~1%C steels. **2. Experience with furnace linings** F. C. Mutitt (550–551) Modifications made to the LD converter linings in the light of experience are described.

Soviet LD steel installation S. G. Afanasev and G. N. Kozin (*J. Met.*, 1960, **12,** July, 552–553) A description of the operation of a top-blown Thomas plant at the Krivoi Rog steelworks (translated from *Metallurg*, 1959, (11)).

Dust removal in oxygen steelmaking (*J. Met.*, 1960, **12,** July, 554–557) Abstracted from a report of a meeting of the Eisenhütte Österreich (of *Stahl Eisen*, 1959, Nov.); deals with techniques used for the removal of dust from the brown smoke produced in the LD process.

Roof wear with automation of an open hearth furnace M. M. Dvorkind and V. S. Korshunov (*Stal'*, 1960, (11), 991–995) In an OH furnace with automated control of heating in which O_2 was fed into the burners and large amounts of tar were used in the fuel, roof temp. showed an increase of 30–40° with variations most acute when fuel was turned off for valve reversal producing 3–4 times as much roof wear. Combined automatic control reduced the limits of heat variation and are expected to increase roof life.

Radiometric investigation of the burning in and wear of open hearth bottoms V. A. Machkovskii and M. M. Khil'ko (*Stal'*, 1960, (11), 996–997) Previously suggested mechanisms of consolidation and wear were examined using radioactive Ca, P, and Sr which were set free into the slag in the course of wear. The theory of Berezhnoi was supported and it is recommended that the highest possible temp. should be used for burning in using mill scale for slagging. Hot repair time is cut and a 4-h programme gives a marked increase in production.

Combustion of sulphur-containing crude oil in open hearth furnaces N. I. Kokarev, A. G. Kapichev, V. G. Lisienko, V. P. Filatov, P. P. Semenenko, and S. F. Aleksandrov (*Stal'*, 1960, (11), 1001) A design for cracking the oil in the form of a mist in the uptake is indicated.

Technical and economic considerations regarding the use of decarburising ores in the 185 t OH furnaces A. Birsan and G. Rebreanu (*Met. Constr. Masini*, 1960, (7), 604–609) This paper deals with ores normally used in the 185 t OH furnaces working the pig iron–scrap-ore process. The assessment of the technical and economic indices of the available ores containing Fe_2O_3, FeO, Fe_3O_4, and $Fe_2O_3.H_2O$ as well as $FeCO_3$ are considered.

Special repair procedures for hot furnaces Devanlay (*Centre Doc. Sid. Circ.*, 1960, (9), 1981–1985) Techniques used for the repair of arches and walls of OH and Maerz-Boelens furnaces are described.—A.D.H.

Experience with the all-basic roof test rig of the United Steel Companies Ltd J. R. Lakin and C. S. West (*Iron Coal Trades Rev.*, 1960, **180,** June 17, 1349–1353) A report of the BISRA Steelmaking Conference paper. Reports on the 'Continental System' as practised at 'Bilston' and by Steel, Peech & Tozer were presented using a test rig which is described and assessed.

Roof construction: American experience W. S. Debenham (*Iron Coal Trades Rev.*, 1960, **180,** June 17, 1354–1358) A report of the BISRA Steelmaking Conference paper. The development of roof design is summarized and present practice is indicated.

Roof construction: experience of Detrick and 'Continental' roofs at Ijmuiden P. W. L. Lanzing (*Iron Coal Trades Rev.*, 1960, **180,** June 17, 1357–1360) A report of the BISRA Steelmaking Conference paper. Two types of brick were compared in furnace roofs of both types. The Detrick construction seemed somewhat superior.

Roof construction: rigid *v.* sprung roofs at the Templeborough melting shop H. H. England (*Iron Coal Trades Rev.*, 1960, **180,** June 17, 1358–1359) A report of the BISRA Steelmaking Conference paper. The rigid A–F roof design proved superior.

Wheeling to increase production through use of oxygen E. H. Johnson jun. (*Iron Steel Eng.*, 1960, **37,** Sept., 220) A description of the tonnage oxygen plant being installed by Wheeling Steel Corp. for use in its Mingo Junction and Steubenville, Ohio, plants and its application to OH refining and oxygen-steam blowing.

Composition and properties of the sintered bottoms of OH furnaces, produced by speeded-up methods P. N. Babin and S. M. Zubakov (*Ogneupory*, 1960, (9), 410–418) In the formation of the new bottoms for OH furnaces by the speeded-up methods, complex interactions occur between the component parts of the materials. The grains of the magnesite powders impregnated with the alloy formed by the additions of OH slags and scale penetrate into the powders and separate into different crystals and blocks of periclase. Spinels of complex composition of di- and tervalent cations are formed (Mg'', Fe'', Mn'', Ca'' Fe''', Al''', and Cr''') and also solid solutions of iron oxides and periclase. During service, the bottom fettled by the rapid method becomes saturated with the oxides from the slag and becomes stronger than in the initial state.

Oxygen in open-hearth steelmaking. BISRA Junior Steelmaking Conference J. Pearson (*Iron Coal Trades Rev.*, 1960, **181,** July 8, 65–71) A report of a survey carried out by BISRA on behalf of the industry, with tabulated details of salient features of practices of leading companies, and suggestions for potential increase in output of the industry.

Improved furnace tapping lance J. Kristowiak (*Iron Steel*, 1960, **33,** Oct., 505) The burner described was developed at Bochumer-Verein Gross-Stahlwerke AG, and will soon be available in Britain. It is made up of a minimum of three tubes, through which O_2 and other fuels are fed, and the time taken to burn out the taphole of an 80-t fixed OH furnace is only 14 sec. An additional type of safety burner is described. Both burners are manufactured by W. Humberg & Co. of Hagen-Haspe.

Modification of the valve changeover process on open hearth furnaces fired with producer gas. II. Explosion-proof and low-loss changeover processes H. Schicke and H. Gauter (*Neue Hütte*, 1960, **5,** Sept., 549–558) Gas losses and cooling of the upper furnace during reversal, flow conditions in various reversal programmes with coupled and individual drives, and proposed modifications for explosion-proof reversal programmes are discussed.

Use of oxygen lances and basic brick in open hearth furnace roofs H. A. Parker and P. Schane jun. (*Iron Steel Eng.*, 1960, **37,** Aug., 176–180) Types of lance, design of basic roofs, and lance installations, and operating results are described, with particular reference to practice at the Fairless Works of US Steel Corp.

Production of killed steel by blowing the open hearth bath with oxygen L. S. Rybakov, N. A. Khudyakov, V. S. Krivonosov, and D. F. Nagovitsyn (*Stal'*, 1960, (12), 1078–1080) The process has been found to have advantages. The maximum effect is obtained by O_2 injections during the melt-down period.

Control of alloy carryover in melting K. M. Shupe and P. Dufresne (*Iron Steel Eng.*, 1960, **37,** Oct., 114–116) A study made at the works of Latrobe Steel Co., Pennsylvania, on the control of the unwanted carry-over of such elements as Co, Cr, Ni, and W from one heat to the next by the use of a melt sequence table.

Firing open hearth furnaces with multiple mobile burners through the roof A. Labat (*Ind. Heat.*, 1960, **27,** Aug., 1642–1648) Working details are given of equipment for inserting water-cooled burners at 45° through the roof to give flames near the surface of the scrap or liquid bath. The apex of the flame attacks the metal, giving better thermal efficiency and cooler roofs. Flexible tubes bring the fuel and water supplies. Operating data show increased production and roof life. Details are given of working installations in France, and oxygen usage is contemplated.—K.E.J.

Final report on producer-gas-fired 30-ton open-hearth furnaces having roof lives of more than 2000 heats A. Schöberl and E. Pink (*Radex-Rundsch.*, 1960, Oct., 243–256) On the occasion of the changeover from producer gas to natural gas for OH furnaces the authors summarize their experience with these 30-t furnaces for producing high-quality steels. The importance of correct combustion and of guiding the flame is stressed. Trials with various types of checker bricks are reported under the present conditions the basic checker bricks have been found superior. The use of a chrome–magnesite lining instead of a silica lining increased roof life up 2672 heats and reduced the heat and brick consumption per t of steel produced.—T.G.

Improved acid open hearth performance by addition of slag to charge K. J. Smith and J. C. Richardson (*BHP Tech. Bull.*, 1960, **4,** March, 26–29) Acid OH steel for rolls is produced in a 40-t producer-gas-fired furnace. For local reasons it had been customary to add coke breeze to the charge, but after melting, the coke rose to the surface, blanketing the bath and causing poor heat transfer and irregular working. The problem was solved by adding with the charge some return slag from the process. Production increases of 15% were obtained and improved smoothness of working. Some experiments suggested that crushed blast-furnace slag could be substituted for the acid slag.

Distribution of phosphorus between the metal and the slag under consideration of the ionic and covalent bonds of the chemical compounds in the slag N. M. Chuiko (*Izvest. Akad. Nauk, Otdel. Tekhn., Met. Toplivo*, 1960, (2), 26–36) An analysis of the results obtained from treating many experimental data, based on the molecular theory of slags, has shown that the equilibrium constant of the dephosphorization reaction at constant temp. is a magnitude depending on the composition of the slags. This paper explains how, based on the theory of the structure of slags and taking into account the ionic and covalent bonds in the chemical compounds of the slags, it is possible to calculate the active concentrations of the ferrous oxides and of the other constituents and calculate the equilibrium constants of dephosphorization and of other reactions.

Mixing of metal and slag in open-hearth furnaces A. I. Osipov and L. A. Shvartsman (*Stal'*, 1955, **16,** (8), 709–713; *HB*–3673, 1960, June; from *US Tech. Trans.*, 1960, **4,** Sept., 290) No abstract.—C.F.C.

A practical method of introducing oxygen into the flame of open-hearth furnaces A. A. Dobrokhotov (*Metallurg*, 1960, (10), 19–21) It is suggested that the angle of inclination of the oxygen tuyeres should be 12°, that the height of the oxygen tuyeres above the lower part of the block should be 150 mm, and that the oxygen tuyeres should be introduced through the body of the block.

Design, construction and operation of the Maerz-Boelens open hearth furnace Keystone Steel and Wire Co. (*Ind. Heat.*, 1960, **27,** Aug., 1685–1692) The all-basic furnace has front and back walls which slope inward over the hearth to the roof, with the cross-sectional area of the furnace assuming a semi-elliptical shape. It is ideal for all cold-charges, and should produce 17·5 t/h tap to tap. Full details are given of the refractories.—K.E.J.

Experience gained with latest open-hearth furnaces of Maerz-Boelens design C. H. Pottgeiser, H. J. Därmann, and E. Knackstedt (*Stahl Eisen*, 1960, **80,** Oct. 27, 1487–1492) The new 150-t capacity Maerz-Boelens OH furnace is described and illustrated. The furnaces run by Dortmund-Hörder Hüttenunion have proved very successful, although it should be pointed out that furnaces which are so compact require a particularly close control of the heat input, of the gas–air mixture, etc. The specific heat consumption was very low. All repair work could be carried out in very short time resulting in an availability of more than 95%.—T.G.

The use of oxygen in a 100-ton Maerz-Boelens open-hearth furnace at Hörde H. J. Krabiell and E. Knackstedt (*Stahl Eisen*, 1960, **80,** Oct. 27, 1492–1496) The already high efficiency of the furnace could be further improved 12% by oxygen admittance below the doghouse. Quantity and time of addition of the

liquid pig iron had a marked effect. The use of O_2 had a beneficial effect on the sulphur level of the steel. Blowing O_2 into the bath gave a further improvement in efficiency. Admittance of O_2 below the doghouse did not impair the life of the lining, but nothing can be said as yet on this point when the O_2 is blown into the bath.—T.G.

Oxygen–fuel roof lances and end burners used in open hearth to increase steel production at Ford Motor Co. (*Ind. Heat.*, 1960, **27,** July, 1427–1428) At the Dearborn works, trials have been made of practice using liquid-fuel end burners with O_2 enriched-flame and O_2-fuel roof lances, on charges of 50% scrap and 50% hot metal with burned lime. Hot metal is added 45 min after the start of the charge. On the 200-t furnace, the total heat time is 3 h, and average production rate is 67·6 t/h; on the 400-t furnace the rate is approx 100 t/h.

Use of oxygen lances and basic brick in open hearth furnace roofs. II H. A. Parker and P. Schane jun. (*Ind. Heat.*, 1960, **27,** July, 1483–1505) Details are given of a basic roof construction featuring suspension with hold-down supports for ridigity. At United States Steel Corp., 40 roof campaigns have been completed and the programme of converting to basic roofs continues. The roof is economical and not greatly sensitive to wide variations in temp., It gives increased production, and additional availability because of long life and fewer delays. The furnace can withstand high driving rates.—K.E.J.

On the influence of slag composition upon the desulphurization of molten steel Y. Nagano (*Sumi. Met.*, 1959, **11,** Oct., 266–270) A correlation between (S)/[S] and slab basicity has been observed, and the slag basicity during various periods was examined. Slag is basic or neutral at melt-down and neutral or acid in the later periods of refining. The Matsuhita correlation between (S)/[S] and Br was not improved.—K.E.J.

Differential calculation and the provision of baffles in cast iron recuperators V. M. Dement'ev and M. S. Shklyar (*Stal'*, 1960, (11), 1042–1045) The method of baffling used in boilers to reduce gas velocity along the heat exchanger tube bundles should, it is suggested, be extended to recuperators. Nomograms are given.

Experience with the use of computers for adjusting heating conditions in open hearth heats M. I. Korobko and V. M. Artynskii (*Stal'*, 1960, (11), 981–984) Trials of computer systems for OH control are described. The use of the experimental SAMP equipment and the use of KETI equipment with a 430-t furnace are reported. A complex parameter ΔQ was constructed representing heat absorption by the bath, and this is evaluated and fed to the computer which supplies the recommended variations in the heating controls.

Synthetic diaphragms extend furnace-controller life Selas Corp. (*Iron Age*, 1960, **185,** June 9, 106–107) The use of synthetic-coated fabrics for diaphragms in gas–air ratio controllers and pressure regulators is recommended. Such materials require less maintenance and last longer than leather diaphragms.

The hot blast cupola: its scope as a premelting plant in steelworks F. Lüth (*Iron Steel*, 1960, **33,** Aug., 418–422) Possibilities include increasing the melting rate of the OH furnace by the use of low-Si metal from the cupola, and the melting of steel scrap in the cupola charge. Economics of different operating methods with and without premelting units are compared.

Some features of basic oxygen steelmaking with basic hot blast cupolas E. R. Richard (*Blast Furn. Steel Plant*, 1960, **48,** Aug., 820–822, 824) The process as worked at the Acme Steel Co.'s plant is described and discussed.

Investigations on manganese distribution between liquid carbon-saturated iron and lime–silica slags at 1550°C H. Schenck, M. G. Frohberg, and T. el Gammal (*Arch. Eisenh.*, 1960, **31,** Oct., 567–569) The Mn distribution was investigated at 1550°C between C-saturated iron and CaO–SiO_2–MnO slags. The results were used to determine the activity coefficient γ^{Si}_{Mn}, which represents the influence of Si on the Mn activity. A simple linear relationship was found between the corrected Mn distribution N_{MnO}/a_{Mn} and the square of the 'basicity value' $B=(N_{CaO})/(N_{SiO_2})$.

Equilibrium measurements between carbon-saturated Mn–Fe–Si melts and CaO–Al_2O_3–MnO–SiO_2 slags E. T. Turkdogan and R. A. Hancock (*Trans. IMM*, 1958–59, **68,** 273–278) The discussion on the paper (1957,–58 **67,** 573–600) is reported.

The Duplex process with arc furnaces. Reasons for its choice. Method and control of melting J. B. Paraguay and W. F. Velloso (*Bol. ABM*, 1960, **16,** Oct., 799–812) A brief account of the development of the automobile industry in Brazil is given and the factors that led to the General Motors plant at Sao José dos Campos are discussed. A furnace capacity of about 8 t/h was required for long runs of three types of iron and the reasons leading to the choice of direct arc furnaces are given. The furnaces are acid-lined, those for primary melting are about 8 t capacity and are basket-charged; the secondary furnace has a capacity of 14 t and is ladle-charged. Each has a dust collection and washing system for the exhaust gases. Details of the method of working are supplied.—P.S.

Some features of basic oxygen steelmaking with basic hot-blast cupolas E. R. Richards (*Iron Steel Eng.*, 1960, **37,** Aug., 174–176) Practice at the Acme Steel Co. plant, Chicago, in the combination of the basic hot-blast cupola using a reducing slag with an oxidizing slag in the oxygen furnace is described. Degree of desulphurization is controlled by slag volume and the CaO/SiO_2 ratio of both slags, making it possible to use a low-cost metallic charge which cannot be employed in the OH furnace and could be uneconomical in the two-slag electric arc furnace process.

Uses of directly reduced iron S. L. Gertsman (*Canad. Dept. Mines, Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 12–13) Trial electric furnace melts of Freeman Corp. and Strategic-Udy irons were made.

Electric iron smelting today and tomorrow F. C. Collin (*Tek. Ukeb.*, 1960, **107,** Oct. 6, 803–813) The present-day position is reviewed, with special reference to production data at the Mo i Rana plant. The Elkem type furnace and process are described, and an account is given of the Elkem pilot plant smelting pre-reduced iron ore and supplying hot metal to the electric furnace.

An 80-ton electric arc furnace at the works of the St Jacques Society at Montlucon M. D. Sauvage (*J. Four. Elect.*, 1960, **65,** July–Aug., 184–186) The processes of production of high-grade and stainless steels, and their history are described with details of plant equipment.

Metallurgical study of electric furnaces G. Grenier (*J. Four Elect.*, 1960, **65,** July–Aug., 177–183) A mathematical study of acid and basic arc furnaces is presented, covering the increase of mean and maximum capacities of the latter between 1910 and 1950, the yields of OH furnaces on ordinary and special steels, the costs of single and double slag operation, the relative yields of electric and OH furnaces, the oxygen consumption of each, according to capacity, rules of decarburization of chrome baths, with a comparison of both processes. **Type examples of production** (Sept.–Oct., 235–238) A short review under four headings: (1) Carbon tool steel, (*a*) without refining, (*b*) with light refining; (2) Hard carbon steel for ropes; (3) Chrome–nickel construction steel; (4) 18–8 Rustless austenitic steel with two methods of manufacture. Detailed lists and diagrams of operations are given, and studies of slags are attached in brief.—S.H.-S.

Control device for the electric current in steel melting arc furnaces A. D. Svenchanskii (*Vestnik Elektroprom.*, 1960, (8), 23–26) The existing automatic time devices for current control do not give reliable service and the mechanism of displacing the electrodes by means of winches is unsatisfactory. A hydraulic control system could remedy these defects but is very complicated, nor can a rack mechanism equal the proposed system of control by means of electromagnetic friction sockets with intermediate amplifiers and semiconductor triodes or with magnetic amplifiers.

Reducing the carbon deposited from the electrode material on the contact clamps in large electric furnaces V. Kravchenko and V. Nikolaev (*Stal'*, 1960, (12), 1106) A note from Zaporozhe. Three or four sections of electrode casing are substituted for the present six or eight, giving better contacts.

How hearth control affects electric-furnace output E. Franzen (*Iron Age*, 1960, **186,** Sept. 8, 106–107) The maintenance of an electric-furnace hearth, its problems and life, with suggestions for its most effective and economical operation, are discussed.—S.H.-S.

Shut-down and start-up procedures for electric furnaces (*AISI Contrib. Met. Steel*, 1960, June, 1–27) A report, containing detailed and tabulated data, collected during the shut-down and start-up periods of the industry-wide strike of 1959, with the object, from a uniform and systematic record, of providing, in the opinion of the Technical Committee on Electric Furnace Steelmaking, means for comparison of practices, and, possibly, identification of optimum practices.—S.H.-S.

Ways of saving electric power in arc steel furnaces L. I. Aronov (*Promyshl. Energ.*, 1960, (6), 10–14) The problem is examined under the heads of the efficiency in the methods of melting and of production; improvement in construction and mechanization of electrical furnaces and the efficiency of the heating schedule especially regarding the automation of the heating cycle. The article reviews the progress made in this direction at different works.

Experience in the treatment of liquid steel with rare earth elements E. D. Verbol'skaya, G. F. Zasetskii, I. V. Isakov, and A. E. Khlebnikov (*Stal'*, 1960, (11), 1030–1033) Liquid Cr–Ni–Mo steel (0·4%C) treated with mischmetal gave reduced S, better impact strength and ductility in the as-cast condition, greater homogeneity, and reduced anisotropy after rolling.

1Kh18N9T steel teemed into ingot moulds dressed with petroleum jelly Yu. G. Gurevich, B. B. Rozin, R. S. Geifman, G. A. Khasin, and B. P. Okhrimovich (*Stal'*, 1960, (12), 1096–1098) Substituting petrolatum for CCl_4 as mould dressing at Zlatoust gave a better surface finish. Teeming temp. should be 1570–1600°C and 2·7 t ingots should be poured in 2–3 min. Dressing time and labour are reduced.

The use of phosphate rock for the manufacture of certain phosphorized steels R. Bashford (*BHP Tech. Bull.*, 1960, **4,** June, 33–35) A temporary shortage of ferro-phosphorus in Australia led to experiments using phosphate rock as a substitute. Tests for making sheet bar by these methods are described and the results tabulated and discussed.—S.H.-S.

The addition of alloying elements to molten steel by reduction of oxides from the slag S. L. Gertsman (*Canad. Dept. Mines. Phys. Met. Div., Res. Special Proj. Rep.*, 1960, Jan. 15, 11–12) The reduction of Nb_2O_5 has been worked out and tests in a direct-arc furnace using Si, Mn, C, and Al as reducing agents have been made. Si and a basic slag should have been the best in theory but on trial a neutral slag was better.

The action of basic open-hearth slag on the magnesium–silicate ladle lining bricks T. A. Aleksandrova and A. N. Alekseeva (*Ogneupory*, 1960, (10), 470–474) Magnesite silicate refractories; dunite, talco–magnesite, and olivines, interact with the basic martensite slags forming in addition to low mp phases (pyroxene-type minerals, monticellite) also high mp compounds (periclases and spinels of complex compositions). Preliminary investigations of the suitability of magnesium silicate refractories as linings for steel melting ladles have shown appreciable adhesion and welding of the slag to the refractories. The suggestion is advanced that the adhesion of the slag is conditioned by the appearance at the refractory-slag interface of these high mp compounds, of complex compositions, which thus increase the viscosity of the fused slag.

The behaviour of sulphur when running open-hearth furnaces on natural gas with auto-carburetting S. F. Karp, I. I. Kobeza, G. I. Mikhailov, and I. A. Goncharov (*Stal'*, 1960,

(12), 1075–1078) Changeover from blast-furnace gas–coke oven gas mixture to natural gas gave greatly reduced sulphur content.

Test of steam cooling of open-hearth furnaces J. Pösner (*Hutník*, 1960, **10**, (9), 335–338) Steam cooling was tested on the works scale in the Bílá Cerkev Steelworks in Czechoslovakia; pressures of up to 15 atmospheres were successfully employed. It is shown that with correct design the method is economical. Water preparation becomes necessary, but the steam can be efficiently utilized apart from its function as furnace coolant. The design of the cooling system, and test data obtained with it, are discussed.—P.F.

Experience gained with the use of natural gas for open-hearth furnaces. I H. Tiemeyer (*Stahl Eisen*, 1961, **81**, Jan. 5, 30–35) Recently, natural gas has been found in Germany in quantities large enough for industrial use. Its main advantage is the absence of sulphur or its compounds, but low calorific value and low ignition velocity require special adjustment of the burners, of the mixture with air and the additional use of carburizers. At present the ratio natural gas:oil is about 1:1. Roof life is often lower when changing to natural gas. Atomization with compressed air and steam are discussed. Waste-gas quantity is usually favourably affected by changing to natural gas. **II** M. Petz (36–41) In this part the changeover to the use of natural gas for a 50-t OH furnace is reported with special emphasis on the modification of the burners and the heat balance. Although the heat consumption increased by 4%, a saving in costs of about 12% could be effected. Furnace practice is more difficult if the furnace is operated with natural gas, for this reason only skilled labour should be employed in its control.—T.G.

Experience gained from the operation of air and gas recuperators H. Babczynski, J. Kokot, and J. Janicki (*Hutník*, 1960, **27**, (7–8), 278–283) After a review of work done by others the authors give their own results and reach the following conclusions; the coefficients of thermal expansion in a section should be kept the same, the use of a fire-resistant recuperator simply for heating the air is not sufficient and an additional gas recuperator should be used.

Operation of the waste-heat boilers attached to open-hearth furnaces M. K. Lin (*Stal'*, 1960, (12), 1151–1152) Installations at the various works are reviewed, operation and costs are considered, and improvements in working and maintenance are suggested.

Determination of the electrical characteristics of an arc furnace J. Ravenscroft (*Inst. Elect. Eng.*, 1960, Preprint 3328, pp.9) Three different methods are described; in the first the characteristics are derived directly from observations during normal operation and under short circuit conditions; the furnace curves in the second are calculated using an equivalent circuit for a 3-phase arc circuit while the third treats the furnace as a balanced 3-phase load and utilizes a current-locus diagram to calculate operating points on the characteristics. This latter is the simplest method. An experimental 10 cwt furnace was used. If the circuit reactance is high, the load current can approach, or exceed the optimum value; it is therefore important that optimum currents should be accurately forecast; it is found that the most efficient operation is obtained when employing the highest voltage tap.—C.V.

Report of the ingot mould sub-committee of the steelmaking division, Steel Technology Joint Research Society (*Tetsu to Hagane*, 1960, **46**, July, 821–939) A special report, dealing with different shapes, compositions, and arrangements of ingot moulds and various types of steel cast.—K.E.J.

Experience gained in the use of thin-walled, seamless continuous-casting moulds B. Tarmann and O. Kleinhagauer (*Stahl Eisen*, 1961, **81**, Jan. 19, 111–119) The reasons for preferring seamless, thin-walled moulds for the continuous casting of steel are discussed with reference to the relation between mould design, mould material, and cooling system. Heat extraction and formation of a shell of the continuous-cast bar, casting velocity, water flow, and taper angle of the mould are considered with particular emphasis on the continuous casting of high-quality steels.—T.G.

Effects of non-oxidizing casting on the qualities of high-carbon chromium steel C. Taniguchi, T. Tanoue, and Y. Kotani (*Sumit. Met.*, 1960, **12**, Jan., 309–311) Five heats were cast in an atm. of N_2 or combustion gas from mould paint. The billets and tubes from the ingots showed reductions in non-metallic inclusions and sand marks.—K.E.J.

An effect of composition on the macro-structure of ingots of a low-alloy steel T. B. Smith, J. S. Thomas, R. Goodall, and R. T. Allsop (*JISI*, 1961, **198**, June, 161–163) [This issue].

Rare earths make ingots homogeneous W. G. Wilson (*Fonderia*, 1960, **9**, Nov., 493–494) The beneficial effect of additions of rare earth metals on iron and steel are described in two recent Russian studies. The ingot skin becomes more homogeneous but the amounts of sulphur just under the skin are greater. This improvement in the skin makes for better hot-working qualities.

The continuous casting of steel 'Metron' (*Tecn. Indust.*, 1960, **38**, Nov., 1956–1957) [In Spanish] A brief account of modern developments in this field is given.—P.S.

Experience with the use of hot tops consisting of combustible plates and of exothermic feeder heads for ingot moulds A. Schöberl and R. Plessing (*Stahl Eisen*, 1961, **81**, Jan. 5, 22–30) The savings in costs effected by various methods of feeding of ingot moulds for plain and high-alloy steels is described and illustrated. The yield in billets could be improved by more than 10% for high-alloy steels, thus giving a reduction in price of 3% by the use of exothermic feeder heads.—T.G.

The use of transparent low m.p. substances to simulate the solidification processes in the ingot S. Ya. Skoblo, E. A. Kazachkov, and V. G. Strakhov (*Izvest. VUZ Chern. Met.*, 1960, (1), 41–46) Special models in the shape of longitudinal sections of the ingot were used which enabled visual observation of the solidification process. The solidifying transparent substance was $Na_2S_2O_3 \cdot 5H_2O$. This pure substance melts in its water of crystallization at 56°. The structure of the hyposulphite ingot resembles that of a metal ingot. This method may be used for practical and scientific purposes.

PRODUCTION OF FERRO-ALLOYS

Establishing a process for the smelting of silico-chrome in one stage Kh. N. Kadarmetov (*Stal'*, 1960, (12), 1106) A note from Chelyabinsk. Electric furnace smelting is described.

Manufacture and properties of atomized, stabilised ferro-silicon 45%Si K. Feldmann and K. Frank (*Schweissen Schneiden*, 1960, **12**, Dec., 514–517) The preparation of ferro-silicon, stabilized by atomization, is described and its properties as an electrode coating are discussed. The importance of grain size and shape is stressed.—R.P.

Labour efficiency in ferro-alloy production F. F. Borodin (*Stal'*, 1960, (12), 1103–1106) Reconstruction of ferrosilicon production with greatly increased automation is planned. Even then improved labour organization and management will be needed.

FOUNDRY PRACTICE

Guide to ferrous castings D. Peckner (*Mat. Des. Eng.*, 1960, **52**, Oct., 127–142) Classification of iron alloys, choice for particular purposes, casting methods, and the design of castings are surveyed with much tabulated data. This is Manual no.176.

Standards and specifications in the foundry G. C. Webster (*Engineer Foundryman*, 1960, **26**, Sept., 24–31) A brief review of standards available for grey irons, manganese steel, copper-base alloys, and the use of tests for castings, followed by a discussion.—S.H.-S.

Modern trends in foundry practice with particular reference to India J. Blakiston (*Found. Trade J.*, 1960, **109**, Aug. 25, 223–230) A review, with a historical introduction and a discussion of practice and raw materials supply.

Temperature control in the foundry H. Connor (*Engineer Foundryman*, 1959, **25**, Dec., 53–54) Various temp. recording instruments used in the Thames Foundry of the Ford Motor Co. Ltd, are described.—C.V.

What does the engineer expect from a casting D. E. Hamm (*Engineer Foundryman*, 1960, **26**, Oct., 23–25) The writer outlines the characteristics a good casting must possess including satisfactory material specification, correct size, appearance and soundness, concluding with a résumé of a discussion on the subject.

Some problems facing South Indian foundries I. Sanghi and R. Ratnam (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 316–319) The low productivity of the small foundry units of South India is analysed. Major difficulties are faulty layout, materials handling, cupola design, and moulding practices.

Some advances in Australian foundry practice as applied in steel industry F. J. Drake (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 53–67) Types of sand used, dry sand moulding practice, and centrifugal casting practice are described.

Recent advances in foundry science F. M. Bunbury and D. V. Atterton (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Tecent Developments in Foundry Technology*, 1958, Feb. 5–8, 69–81) The earlier part of the report deals with non-ferrous metals, but the latter part includes a review of the CO_2 process, shell moulding, and exothermic feeding (28 refs).

Founders hear comparison of converters, electrics F. E. Van Voris and J. Crane (*Steel*, 1960, **147**, Aug. 1, 90) The capital cost (per annual t) and the production cost (per t) for an electric furnace are compared with those for a cupola-converter, showing lower costs for the electric furnace.—S.H.-S.

The use of the 'shaking ladle' in iron foundries S. Tunder (*Koh. Lapok-Öntöde*, 1960, **11**, Feb., 25–31) The construction and use of 3–15 t 'shaking ladles' for desulphurizing and alloying molten cast iron in West-German foundries are described. Bigger, 30–80 t units may be used in steelworks for partial refining of hot-metal with an O_2 blast.

Oxy-acetylene processes in foundry practice R. Ghosh (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8 358–362) A number of applications are described, in outline, including oxy-acetylene welding and cutting, oxygen and oxy-thermic lancing, powder processes, flame softening, and metal spraying.

Metal scrap resources for foundry practice L. L. Zusman (*Lit. Proizv.*, 1960, (10), 1–3) A review is given of the resources of scrap iron available to foundry production, with particular reference to the USSR during 1953–8. Scrap used is classified with a view to showing how the best quality can be obtained by proper organization.

Application of radioisotopes in the foundry S. Wadewitz (*Giessereitechn.*, 1960, **6**, Oct., 311–312) A report of a lecture delivered to the Kolloquium at the Zentralinstitut für Giessereitechnik in April 1960, dealing with fundamentals of the application of radioisotopes to foundry problems. The various investigations being carried out at present in the German Democratic Republic with the aid of radioisotopes are very briefly listed.—T.G.

Technical vocabulary and the International Dictionary of foundry terms P. Huberson (*Inst. Hierro Acero*, 1960, **13**, July–Sept., 701–713) The problem of communication is discussed and illustrated by reference to the evolution of technical language, internal and international definitions of words, and patent writing. The problem of translation is considered and the work of the *Centre Technique des Industries de la Fonderie*, in this field is described. An outline of the plan, work, and scope of the International Dictionary is given (16 refs).—P.S.

Grain size in cast iron (*Bradley's Mag.*, 1960, Spring, 7) A note on work by BCIRA.

A new way of producing manufactured articles directly from a melt A. V. Stepanov (**Vestnik Mashin.*, 1959, (11), 47–49) Use is

made of capillary forces in the direct production of such products as plates and tubes. The equipment consists of a shaping device, e.g. a floating former and cooler, withdrawing and receiving mechanism, and control devices. Molten metal adheres to the plug which is withdrawn from the melt.

Cast iron inserts in aluminium die castings A. F. Baur (*Prec. Met. Mold.*, 1960, May, 42–43) A description is given of the new bimetallic interlock bond which holds cast iron inserts in Al die castings.

The recent development of Japanese foundry industry H. Tanimura (*Indian Construction News, Special No.*, 1958, **7,** Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 83–91) Machine, ingot, malleable and ductile iron moulding are described, including a table giving typical compositions of cast iron rolls. The steel casting industry is described briefly.

Mechanized foundry in North Wales (*Metallurgia*, 1960, **61,** June, 269–271) The construction and layout are described of the new foundry installed by Austin Hopkinson & Co. at Penygroes, Carnarvonshire.

Some problems in the progress made in the Matapanow Works in 1959–60 J. Kocur and H. Wystrach (*Prz. Odlew.*, 1960, **10,** (10), 284–291) The solutions obtained for current problems are illustrated by the following achievements: (1) the application of bottle pressure risers; (2) 'Tetral 30/10' has replaced 'C' oil in core manufacture; (3) the use of plastic patterns (4) the casting of steel under gas pressure; (5) the prolongation of the life of electric arc furnace roofs; (6) the production of railway turnouts from Mn steels; (7) the use of exothermic mixtures for the preheating of risers.

Modern features characterize new Sulzer Brothers Foundry A. Kugler and F. Eisermann (*Foundry*, 1960, **88,** Aug., 102–104, 107, 110, 112, 115; condensed from *Sulzer Techn. Rev.*) The foundry, its layout, equipment, operation, and products are described. It produces castings from 200 lb to 120 t.—S.H.-S.

Man to Man. A visit to a good foundry R. L. Lee (*Foundry*, 1960, **88,** Aug., 139–140) A popular account of a visit to the Traverse City Ironworks, Traverse City, Mich. is given.

Some important aspects of planning foundry layout N. G. Chakrabarty and S. S. Karnard (*Indian Construction News, Special No.*, 1958, **7,** Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 330–335) Factors considered are: production capacity, selection of site and equipment, design of building material flow and storage, quality control, methods, planning, and preventive maintenance.

Rational modernization of foundries A. M. Plesinger (*Indian Construction News, Special No.*, 1958, **7,** Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 336–344) Mechanization and the economical use of moulding space are considered, with illustrative example.

Foundry mechanization C. V. Nass (*Indian Construction News, Special No.*, 1958, **7,** Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 320–329) Details are given of the operation of the mechanized foundry of Worth Manufacturing Company, which is engaged entirely on production work with only five or six different patterns used in any one day.

Foundry mechanization and layout with particular reference to ingot mould production A. E. Crawley (*Indian Construction News, Special No.*, 1958, **7,** Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 292–308) A detailed practical account, with a number of illustrations.

Planning, controlling and following-up of delivery times in foundries A. Obergethmann (*Giesserei*, 1960, **47,** Sept. 22, 530–533).

The research laboratory and foundry practice J. P. Schotsmans (*Indian Construction News, Special No.*, 1958, **7,** Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 386–394). Various aspects of research laboratory work are reviewed, and the functions of a pilot foundry discussed.

Conveyor system speeds handling of large castings (*Foundry*, 1960, **88,** Aug., 132–134, 136) The system with circuitous free track in use at the plant of Scullin Steel Co., St Louis, is briefly described.—S.H.-S. **Conveyors link free tracks to move huge castings** (*Iron Age*, 1960, **185,** June 16, 126–127) A system of overhead tracks for conveying and storing heavy railway castings is described.

Review of the effects of melting practice and superheating of cast iron on quality and mechanical properties K. Orths (*Giesserei*, 1960, **47,** Nov. 3, 595–608) This is a comprehensive review of melting practice for the production of sound iron castings at competitive costs. The author advocates the importance of superheating for 'cleaning' the melt and homogenizing it. By 'cleaning' is meant the removal of oxide inclusions, but even irons that are free from these inclusions require superheating for optimum quality and homogeneity. In this respect melting practice and temp. control, choice of the right moment for pouring, effect on mechanical properties, and consistency in quality are discussed (67 refs).—T.G.

The crucible coreless induction furnace for the re-use of turnings and light scrap A. Tagliaferri (*Fonderia*, 1960, **9,** Dec., 527–532) The note describes various uses of the coreless induction furnace showing that it covers the entire range of normal or special irons. It is well adapted to melting and remelting scrap once regarded as unusable and achieves absolute purity and good quality in that alloy adjustments can be made which speed up operations.

Use of the mains-frequency crucible type induction furnace in the iron and steelmaking foundry M. Jaumain and J.-P. Aymard (*Fonderie*, 1960, May, 189–200) A report on visits to a number of German foundries, making malleable, nodular, and special quality grey irons, and steel. Cold, duplex, and mixed charges were used.

The principal grades of cast iron M. J. C. Margerie (*J. d'Inf. Tech. Indus. Fonderie*, 1960, Sept., (119), 15–19; Oct., (120), 15–21) A brief review of fundamental data on types of cast iron in current use, their composition, and fields of utilization. The study of white-heart cast iron, nodular cast iron, and unalloyed machine iron with their analysis and control are then briefly presented.—S.H.-S.

The distribution of the alloy elements in the formation of the structure of white iron I. E. Lev (*Izvest. VUZ Chern. Met.*, 1960, (2), 148–150) The general conclusion as regards the effect of the rate of cooling on the distribution of the alloy elements between phases is that with an increase in the rate of cooling the selective distribution of the alloy elements is retarded and that this slowing down is greater the higher the rate of cooling and the slower the diffusion of the given element.

Influences of nitrogen on the mechanical properties of cast iron C. Hisatsune and Y. Ueda (*Suiyokwai-Shi*, 1955, **12,** June, 519–522) $CaCN_2$, $K_4Fe(CN)_6$; $K_3Fe(CN)_6$, and gaseous N_2 etc. were added to molten pig iron, and the influences of the nitrogen content on the mechanical properties were examined.

High-quality cast irons made by introducing nitrogen by means of calcium cyanamide N. Volianik (*Fonderie*, 1960, Aug., 307–324) The effect of nitrogen (generated *in situ*) on the properties and structure of cast iron is discussed. Lamellar graphite tends to become nodular. The method of injection results in a graphitizing effect and avoids inoculation. The treatment applies to hypo- and hyper-eutectic cast irons but the quantity of cyanamide introduced appears to depend on the carbon equivalent of the metal to be treated (13 refs).

Present knowledge about the production of castings in high strength irons N. G. Chokrabarti (*Tecn. Indust.*, 1960, **38,** Nov., 1947–1950) Desirable microstructures for high strength cast irons, and means for their control, are described. Choice of composition, properties, and production methods are discussed.—P.S.

Influence of purging with methane of liquid iron on casting quality L. Sofroni, G. Cosneanu, and E. Nicoloiu (*Fonderia*, 1960, **9,** Nov., 467–471, from *Studii Cetari Met.*, 1959, **4,** (1)). The results of experiments carried out confirm that purging with methane is a sure method of improving the quality of the castings and the mechanical properties of the iron. Compactness of the castings is improved, tendency to formation shrinkage cavities, and tensions are reduced as also the tendency to cracking in hot and cold conditions. CH_4 is much less costly to use than argon, nitrogen, CO_2, hydrogen, etc.

Investigation on cast iron having refined graphite produced by melting cast iron covering with slag containing TiO_2(X) H. Sawamura and M. Tsuda (*Suiyokwai-Shi*, 1958, **13,** Sept., 436–441) In 8–H cast iron, ~0·2%Ti is always present in the form of TiC. In this investigation, the following facts were confirmed as inferred from the results of the thermodynamic investigation on the behaviour of Ti contained in 8–H cast iron (Report VII): (1) a part of the TiC exists in the solid state in the molten cast iron (2) the remainder precipitates in the cast iron during cooling from its casting temp. down to ~800°C.—R.S.F.C.

On the fluidity of 8–H cast iron S. Morita, R. Ozaki, and T. Onishi (*Suiyokwai-Shi*, 1958, **13,** Sept., 442–445) The fluidity (running quality) of the so-called 8–H cast iron having fine eutectic graphite structures, produced by treating molten cast iron with slag containing TiO_2 was measured by using a shell mould spiral test apparatus newly designed by the authors, and the following results were obtained: the fluidity of 8–H cast iron containing about 3·5%C, 2·0%Si, and 0·15%Ti was much the same as that of plain cast iron having almost the same chemical composition except for the 0·8%Ti, and was not influenced by addition of up to 1·5%Mn and Cr but decreased on addition of 0·25%Mo and increased above the original value by addition of 0·5 to 0·75%Mo. The fluidity of 8–H cast iron containing about 3·7%C, 2·2%Si, 0·9%Mn, and 0·2%Ti was not influenced by addition of about 0·3%Cr and Mo, individually or in combination.—R.S.F.C.

Production, application and economics of spheroidal-graphite iron R. Burleigh and H. Turner (*Found. Trade J.*, 1960, **109,** Dec. 15, 755–762) A review of work done by International Combustion Ltd to evolve equipment and techniques.—C.V.

Some mechanical properties of cupola malleable iron J. Pelleg (*Foundry*, 1960, **88,** Oct., 110–113) Results of tests conducted during a five-year period, reflecting production experience with cupola-melted malleable iron, made in the laboratories of Taas (Military Industries) in Israel, are presented, and the effect of carbon equivalent and percentage of pearlite in the matrix on mechanical properties are discussed.—S.H.-S.

New gas-tight pots for use in the production of malleable cast iron S. Drápal and J. Rydlo (*Slévárenství*, 1960, **8,** (11), 379–383) Considerable economies are shown to result from using gas-tight bins. The ductility of the blackheart malleable iron so obtained is slightly less than that of malleable iron heat-treated under ore, but if the process is carried out correctly the ductility prescribed by Czechoslovak Standard Specifications is readily exceeded.

A study on the characteristics of bearing alloys (4th Report. Properties of the oilless cast iron bearing T. Matsuyama and T. Kayada (*Bull. Japan. Soc. Mech. Eng.*, 1960, **3,** Nov., 566–571) [In English] As a result of investigations on the properties of cast iron for oilless bearing material for friction and wear the following conclusions are drawn: (1) the growth of cast iron ceased after heating and cooling were repeated about 60 times. The amount of oil with which the grown cast iron was saturated was greatly affected by the viscosity of the oil and, to a minor degree, by the kinds of oil at high temp. (2) When the grown cast iron was saturated with high viscosity oil, the temp. of contact surfaces became finally constant even under heavy loads. (3) Even when lubricant was not supplied, wear was very small and not affected so much by the number of treatments or kinds of saturating oil.

On the relation between casting structure and carbon content of high manganese cast steel M. Asano and N. Ogura (*Suiyokwai-Shi*, 1959, **13,** Aug., 781–784) Three types of cementite were distinguished besides pearlite, and an expression for austenitizing time as a function of C content is given.

Unusual stainless steel casting A. P. V. Paramount Ltd (*Found. Trades J.*, 1960, **109**, Dec. 1, 689–692) This was a pedestal for a candelabrum which apart from the design, had to be cast in corrosion-resistant steel. The various problems, and their solutions are discussed.—C.V.

Sand practice (*BSFA Bull.*, 1960, **2**, Aug., pp.15) A review. Both mechanized and older methods are discussed, 15 examples of plant and processes being illustrated.—C.V.

Installation of a sand shop A. Bonneau (*Fonderie*, 1960, Sept., 371–382) After brief remarks on sand preparation, the author deals with the layout of a sand shop, with special reference to mechanization. Economic and practical aspects of a new sand shop are discussed.—R.P.

New sand system for Canadian Steel Foundries R. Perrault (*Can. Metalw.*, 1960, **23**, July, 29–31) The modernized plant at Montreal divides the sand system into five, sand unloading, dead to live storage, sand preparation and distribution, sand return, and sand reclamation. Each of these sections has an automatic control centre since each differs from the other in complexity and sequence of operation. The operation of each section is briefly described and layouts are illustrated.

Experience with the mechanization of the foundry shop at the 'Stankolit' works N. L. Sobol' (*Lit. Proizv.*, 1960, (9), 17–18) The article describes the mechanization of the burden distribution and the opening and closing of the cupola bottom. Some structural details of the necessary auxiliary devices are given.

Pressure-poured steel: a key to lower-cost steel mill operations? F. W. Starratt (*J. Met.*, 1960, **12**, Sept., 698–699) A description of the controlled-pressure technique developed by Griffin Wheel Co., a subsidiary of American Steel Foundries, to the casting of railway car wheels. Experiments have indicated the possibility of applying the process to the casting of semi-rolled shapes, with the elimination of the primary mill and soaking pit.

Reconstruction of the cupolas of the foundry shop at the Gor'kii Motor Works A. R. Komarov (*Lit. Proizv.*, 1960, 9), 16–17) The cupolas for the production of forging and sulphur irons were reconstructed with a view to increasing yield and partly replacing coke by gas. These cupolas of 10 and 15 t/h capacity, after conversion to coke and gas fuel, had an increased capacity of 12 and 18 t/h respectively. In addition, two of them are now working with supplements of natural gas. Coke consumption has been reduced by 30%. Drawings and structural details are supplied.

Bucket hoists for charging cupolas G. Z. Lipovetskii and N. S. Morozovskii (*Lit. Proizv.*, 1960, (9), 21–25) Bucket hoists for charging cupolas of 5 t/h capacity at the Taganrog combine are described. They consist principally of a rigid metal frame, trolley with hinged attachments for the buckets, a double conveyor with electric motor. Drawings and specifications are given.

Knocked-out moulding mass used instead of refractory bricks I. M. Tsiperfin (*Lit. Proizv.*, 1960, (9), 41) In the foundry shop of the Odessa Works, two 600 mm dia cupolas are now lined with knocked-out moulding mass which is rammed by hand round the hearth to a height of 800–1000 mm above the first row of tuyeres. The service life of this lining is equal to that ot a chamotte brick and gives satisfactory results.

Recuperator for cupolas of up to 5 t/h capacity I. B. Khazan (*Lit. Proizv.*, 1960, (9), 19–21) The air preheater is made of 4 mm thick heat resistant Kh18N20S2 steel which is resistant to flue gases up to 1000°. In contrast with convection recuperators it does not need a unit for systematic dust removal. A maintenance cleaning of the recuperator is carried out every 2–3 months by means of compressed air. This radiation recuperator has been designed by NIITraktorosel'khomash and is calculated to heat 4000 m³ of air/h to 300°. If attached to a 5000 m³/h cupola, its cross-section has to be increased by 20% which negligibly reduces the hot air temp.

Consistent cupola operation R. Jelley (*Brit. Found.*, 1960, **53**, Sept., 389–392) The factors affecting consistent cupola practice in an automobile cylinder foundry are discussed and details are given of the routine controls necessary to give iron of high temp. and consistent analysis.—A.D.H.

Aerodynamics of cupola operation (*Castings*, 1960, **6**, May, 29–31) A reprint of an article from 'Coal Research in CSIRO', 1959, Nov.

A 20 t/h capacity cupola run on coke-oven gas with preheated air blast and water-cooled melting zone A. V. Skvortsov (*Lit. Proizv.*, 1960, (9), 13–16) This cupola was designed by Gipromez. Drawings and descriptions are given. It is provided with automatic control of temp., gas pressure in the stack, hot air pressure, temp. of the liquid iron, etc.

Experience with a gas-fired cupola P. L. Shkurupii and A. G. Arnopolin (*Lit. Proizv.*, 1960, (9), 12–13) A special cupola is described which may run on coke, coke with gas, or gas alone. It consists mainly of the frame of a normal cupola with one row of tuyeres, air booster pipe, two-duct burners, other burners, and gas reservoirs. It has given good results under actual conditions of production.

The development of the cupola process N. A. Barinov (*Lit. Proizv.*, 1960, (9), 1–5) Mainly a description of a cupola of recent design with internal water cooling and different linings. Also a description of the melting process, slag control, carbon content control, dephosphorization, etc.

The reactions in the metallurgical basic cupola (MBC) R. Doa (*Lit. Proizv.*, 1960, (9), 28–33) The article is a rather detailed study of the processes taking place in this cupola and is based on a large volume of experimental work. From the results of these investigations it is possible to conclude that the carburizing of the metal is weak at tuyere level but increases considerably in the zone 300 mm below them. Carburization in the MBC does not seem to depend on the S content, neither does the Si or P concentration influence carburization. Regarding the slags it may be concluded that an appreciable reduction of FeO content takes place in the hearth zone but that the reduction still remains incomplete.

Effects of moisture contained in the blast of the cupola K. Abe and C. Saito (*Imono*, 1960, **32**, June, 402–409) Tests performed on the effects of moisture on the blast in the conditions of cupola operation and the quality of the molten iron are presented and the results described.—S.R.-S.

Desulphurization of the iron for wheel casting S. A. Mikulin, A. G. Kolesnichenko, and G. A. Baidak (*Lit. Proizv.*, 1960, (9), 42) Soda in lump is added to the charge which gives better results than soda as powder. The pieces are prepared by putting 15–20 kg powdered soda into a tank with 10–12 l water and, after 2–5 h, evaporating the super-saturated solution to a hard mass which is then broken up in pieces of about 0·5 kg. These are added to the charge at the rate of 200 g to 200 kg metal.

Computer for calculating the heating process of the cupola L. M. Marienbakh and A. M. Shapiro (*Lit. Proizv.*, 1960, (9), 25–28) The data read from a nomogram are fed into a calculating machine consisting of two blocks and a current stabilizer. The first block carries out the calculations for coke consumption according to a pre-determined equation and the second the air consumption, also according to a program built into the unit. Details are given for the construction of the two blocks and of the electrical diagram.

Superheating the cupola iron G. G. Shepel' (*Lit. Proizv.*, 1960, (9), 40–41) Experience has shown that it is possible to achieve a superheating of the iron in the cupola with 'blown-hearth', when 10–20% of the air blast passes through the hearth into the forehearth causing partial combustion of the gases there and additional superheating of the metal. The gases from the hearth which penetrate into the forehearth have, in addition to a considerable quantity of sensible heat, a certain calorific value (about 430 kcal/m³). Hence their combustion in the forehearth is an additional source of heat for superheating the iron. A device has been worked out which can be incorporated in cupolas of up to 5 t/h capacity for enriching the forehearth gases with the partly burnt gases from the hearth and for their combustion in the forehearth. Drawings and specifications are supplied.

Duplex fusion, cupola: electric furnace T. Kitice (*Bol. ABM*, 1960, **16**, Oct., 757–765) The operation of a cupola-direct arc furnace process for producing malleable iron for the automobile industry is described. The method is capable of strict control and leads to a uniformity of product.—P.S.

Observations on the battery of low frequency induction furnaces of Ford Motor of Brazil, in Osasco, SP J. M. Branco Ribeiro (*Bol. ABM*, 1960, **16**, Oct., 723–740) A description of the control and operation of the set of three 8 t low-frequency induction furnaces is given at the stage where they have produced about 16000 t of cast irons of the Si–Mn–Cr type (typical analysis, 3·44%C, 2·25%Si, 0·71%Mn, and 0·33%Cr). The furnaces are of acid monolithic construction with an average lining life of 400 t. The two years' operational experience has confirmed that the anticipated advantages have been achieved.—P.S.

Mineral formation in the silica crucible of an induction steel-melting furnace L. I. Karykian and L. A. Tseitlin (*Doklady Akad Nauk*, 1960, **130**, (5), 1091–1094) The mineralogical content of a silica crucible is given after a service life of 30 melts at between 1530 and 1550° in an induction furnace of 250 kg capacity. The composition of the original crucible material is tabulated together with the composition of the steel melted and the results of the macro and microscopic examination of the various zones of the crucible.

Experience gained in the operation of the 250-kg medium-frequency induction furnace, IMSK 250 D. Mollitor (*Giessereitechn.*, 1960, **6**, Oct., 297–299) A medium-frequency induction furnace of 250 kg capacity having an input of 150 kW for the melting of acid resistant steel is described and details of its operation are reported. The steel is of the 18:8-type and is used mainly for casting of dairy machinery parts. Difficulties experienced from the presence of silicate inclusions in the castings could be eliminated by modifications of the slagging practice.—T.G.

Influence of sulphur on the mechanical characteristics of high quality grey cast irons J. Vazquez White (*Inst. Hierro Acero*, 1960, **13**, July–Sept., 760–768) Following a general consideration of the effect of sulphur in cast irons, a report is given of mechanical tests of about 180 samples of high quality cast iron (3·20–3·30%C, 0·55–0·70%Mn, 1·45–1·70%Si, 0·22–0·25%P) with between 0·010 and 0·180%S. It is shown that it is necessary to hold the sulphur content between 0·095 and 0·180% in order to maintain the requisite properties and avoid hard zones. Only 20% of the test-pieces with sulphur contents between 0·01 and 0·095% reached the required tensile strength and only 50% the required hardness.—P.S.

The use of antimony-containing cast iron instead of bronze A. I. Smirnov and B. V. Chelpanov (*Stanki Inst.*, 1960, **31**, (10), 29–31) Antimony-containing cast iron is much more wear-resistant than bronze or grey pearlite cast irons. It has high anti-friction and anti-corrosion properties, and is not an expensive material.

On spherulite formation in metal melts H. H. Stadelmaier (*Z. Metallk.*, 1960, **51**, Oct., 601–604) The author reviews current theories on the formation and growth of spherulites in metal melts. The vapour-bubble theory is explained and observations on iron–tin–graphite alloys are described. Tin has a very high vapour pressure and forms vapour bubbles in the iron melt. The growth mechanism of the spherulites is deduced from polarized-light microscopy. These observations were also made on a number of non-ferrous alloys (13 refs).—T.G.

Spheroidal graphite cast iron: Present position of research and industrial development H. Grossmann (*Giessereitechn.*, 1960, **6**, Oct., 314) A report of a lecture delivered to the Kolloquium at the Zentralinstitute für Giessereitechnik in April 1960. Three research tasks are in hand at present: Heat-treatment of spheroidal graphite cast iron, permanent-mould casting, and injection of Mg into the melt. The

injection of Mg gives great difficulties as the jets clog up and no remedy has so far been found. The author complains that the industrial introduction of spheroidal graphite cast iron is over and over again retarded: not being able to keep any promises for its delivery has a bad effect on the consumer industry which waits in vain for the supply of the new material.—T.G.

The static and dynamic strength properties of spheroidal graphite cast iron H. Mühlberger (*Giesserei*, 1960, **47**, Nov. 3, 616–622) The author discusses the static and dynamic strength properties of cast irons produced by different melting practices, which show that iron produced in the electric furnace is superior. Tables and graphs show the property data of ferritic and pearlitic cast irons with spheroidal graphite.—T.G.

The production of nodular cast iron in a tightly closed ladle A. Jankowsky, J. Piaskowsky, and J. Kumor (*Koh. Lapok-Öntöde*, 1960, **11**, March, 55–59) The inoculation of molten cast iron with bars of Mg or Electron metal in a tightly closed ladle is described.

S.G. iron-foundry technology D. K. Coutts and S. N. A. Narayan (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 119–124) Topics dealt with include—the use of electric furnaces and basic cupolas for the melting of ductile iron, inoculation methods, founding techniques, and properties and applications.

The manufacture of rolls of spheroidal graphite cast iron with indefinite and part chill rolls B. Raczynski (*Prz. Odlew.*, 1960, **10**, (9), 263–266) The metal is obtained from an OH furnace of 25 t capacity. Mg is added under a bell. The rolls, of undefined chill (B.H.420–480) are cast in cast-iron dies coated with a thin layer of blacking. Part chilled rolls are cast in dies with a moulding material layer about 10–15 mm thick. The rolls thus manufactured show a satisfactory life.

High-duty malleable iron K. Roesch (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 111–118) A review of types of malleable iron, processing techniques, and mechanical properties, with emphasis on the need for careful control to produce high-duty iron of consistent quality.

Short-time malleablizing H. Krüger (*Giessereitechn.*, 1960, **6**, Oct., 312–314) A report of a lecture delivered to the Kolloquium at the Zentralinstitut für Giessereitechnik in April 1960. The author reviews the theory of short-time malleablizing and then describes the practice as applied by a works in Western Germany.—T.G.

Malleablizing of cast iron in a gaseous atmosphere E. Chapo (*Koh. Lapok-Öntöde*, 1960, **11**, March, 49–55) The author describes small-scale experiments on the malleablizing of cast iron in a gaseous atmosphere composed of CO, CO_2, H_2, and H_2O.—P.K.

Present condition of ductile cast iron castings in Japan K. Tanaka (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 125–128) Manufacturing techniques and applications are outlined.

Malleable casters cash in on product redesign (*Steel*, 1960, **146**, June 13, 158–159) Prize-winning entries in a design contest sponsored by Cleveland Malleable Founders Society are described.—D.L.C.P.

Steel founding (*Métal. Constr. Mécan.*, 1960, **92**, Sept., 655, 657–659, 661) A continuation of recommendations by the Association Française des Aciéries de Moulage, comprising rules applicable to layout; comments on a specimen call for tenders; and special advantages of moulding. Examples are illustrated and analysed.

Cast steel components benefit fabricator, user (*Steel*, 1960, **147**, Aug. 8, 88–89) Redesign of equipment or machinery to use steel castings, including the use of multiple moulds, is suggested by the Steel Founders' Society of America as offering short cuts to the fabricator and benefits to the user.—S.H.-S.

The production of cast-steel flanged-fittings J. Pribyl (*Koh. Lapok-Öntöde*, 1960, **11**, March, 60–63) A new Czechoslovak method for the casting of steel flanged-fittings is described.

Role of National Metallurgical Laboratory in research and development of foundry sands and moulding materials B. R. Nijhawan (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 31–41) A survey of Indian sands and bonding materials (24 refs).

Indigenous bonding clays and scope for their development R. M. Krishnan, B. V. Somayajulu, and B. R. Nijhawan (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 246–252) Indian deposits of bentonite and fuller's earth are enumerated, and trials in the use of four different types of bentonite and one of fuller's earth (from Rajasthan) are described and the results assessed.

High quality zircon moulds J. Just (*Hutnik*, 1960, **27**, (4), 151–154) The article deals with the use of zircon compositions as an additive (from 10% to 85%) to moulding sand. The following conclusions are drawn: The resulting steel casting is not contaminated by mould erosion; the mould surface remains smooth under most conditions; higher casting temp. can be tolerated, and Mn and Cr–Ni steels can be cast without difficulty.

Furfuryl alcohol is base for new type sand binder Archer-Damels-Midland Co., Aristo Corp., and Quaker Oats Co.—Chemical Dept (*Foundry*, 1960, **88**, Aug., 128, 130) The general properties of a new type of sand binder base on resinified furfuryl alcohol, and its use, are described.—S.H.-S.

Aspects on olivine sand as moulding material in steel foundries K. Beckius and A. Huldt (*Jernkont. Ann.*, 1960, **144**, (9), 708–736) [In English] The paper is based on a report issued by a research committee of Jernkontoret on an investigation into the properties of olivine sand. The geology and physical properties of the sand, and health aspects, were investigated and its suitability as a steel foundry moulding sand compared with that of silica sand (33 refs).

Revised specification for gray iron castings includes major changes E. Bremer (*Foundry*, 1960, **88**, Sept., 144–147) A summary of many important changes included in recently issued revised ASTM specifications for grey iron castings, with tabulated requirements for the tensile strength of grey cast irons in separately cast test bars, rules for dimensional data for tension test specimens, and four definitions of lots of castings.—S.H.-S.

Cast iron. Report of Committee A-3 (*ASTM Preprint* 2, 1960, pp.13) Proposed tentative specifications for austenitic nodular iron castings, and for ferritic nodular castings for valves, flanges, pipe fittings, and other piping components are included.

Casting gray iron cylinders on integrated mould and core line R. H. Herrmann (*Foundry*, 1960, **88**, Sept., 158–162) Finned, air-cooled cylinders used in the Convair air-cooled engine are cast in assemblies of shell moulds at the foundry of Chevrolet Motor Div., GMC, Tonawanda, NY. The making of moulds and cores of resin-coated sand in blowing machines on the same line is described and various stages of the process are illustrated.—S.H.-S.

Cast iron parts for the automobile industry L. M. de Faria (*Bol. ABM*, 1960, **16**, Oct., 751–757) The general problem of supplying cast iron to the automobile industry is discussed. Means of meeting the demand of the Brazilian industry for grey and malleable cast irons are considered.—P.S.

Tellurium in cast iron improves soundness but has an adverse effect on microstructure and mechanical properties G. D. Liljenström and K. E. L. Nicholas (*BCIRA J.*, 1960, **8**, Sept., 680–694) Improvements in the soundness of grey iron castings resulting from the introduction of trace quantities of Te have been assessed with light and heavy section test castings, Te being introduced as a mould wash, mixed with a facing sand or as a direct addition to the melt. Inoculated and uninoculated irons were compared. The most important effect is a marked reduction in the severity of internal porosity. It is suggested that tellurium improves soundness by reducing the extent of casting expansion during solidification. Tests have also shown that in addition to producing surface chill, Te adversely affects graphite structure and mechanical properties. The results of the examination of test bars for shrinkage and degree of nucleation are tabulated, and the effect of Te on structure is illustrated by macrographs and micrographs.—S.H.-S.

Influence of silicon and manganese on the casting structure of white iron M. Ibaraki and T. Okamoto (*Imono*, 1960, **32**, July, 482–490) Tests for the determination of the effects of Si and Mn on the casting structure of solute iron are described and results are presented.

Inoculating magnesium iron with ferrosilicon in the pouring spout of the cupolas V. A. Pokrovskii (*Lit. Proizv.*, 1960, (8), 44–45) In the manufacture of cast crankshafts at the 'Volga' Motor-car works, 0·35%Fe–Si of 75% quality is introduced into the liquid metal 2 min before pouring. The structure of the iron consists of a considerable proportion of ledeburite, especially at certain positions in the shaft. In order to do away with a graphitizing anneal and to achieve liquation in the chilled portions of the castings, the mould was filled by pouring through a layer of Fe–Si in a special funnel with a filter mesh. The Fe–Si was of such a size as completely to dissolve in a time interval corresponding to the time of pouring. The spheroidal graphite inclusions under these conditions increased in number.

Review of ductile iron. I. The metallurgy of ductile iron K. D. Millis (*J. Met.*, 1960, **12**, June, 459–463) A paper on the effect of the shape of graphite on the properties of cast iron.

Sponge iron use in production of steel castings J. R. Small (*Foundry*, 1960, **88**, Sept., 152–155) A paper presented in Los Angeles at a meeting of the Steel Founders' Society of America by the chief metallurgist of Stanley Foundries Inc., Inglewood, Calif., describing how sponge iron has been adopted as melting stock for various types of steel castings, and summarizing its advantages, physically, economically, chemically, and metallurgically.

Investigation of solidification of high strength steel castings under simulated production conditions (*PB* 151753, 1958, July, pp.52) Cooling rates from 300° to 20°F/min with gradients from 350° to <70°F per inch were used. Macrostructure showed little change but microstructure was modified, microporosity appeared in the central portions of all plates.

Anti-burning moulding materials A. N. Tsibrik (*Lit. Proizv.*, 1960, (8), 2–4) The mixtures must have good cooling properties, not be wetted by the liquid metal, must be able to accumulate heat, have also good thermal resistance, and be chemically inert. Such materials, which are now being used in increasing proportions, are zircon sands, pyrophyllite, mullite, corundum, silicon carbides, etc. Some formulae for suitable mixtures are given.

Mobile sand preparation device model No.126 P. G. Chistilin (*Lit. Proizv.*, 1960, (8), 20) A brief description is given of the machine the technical characteristics of which are: capacity 8 and 12 m^3/h with two and three operatives respectively; dia. mixing drum 350 mm; 950 rpm; rate of ejection 17 m/sec; area of sieve 0·45 m^3; electric motor 2·8 kW; overall measurements 2200 mm × 920 mm × 1400 mm; total weight 590 kg.

pH control of moulding materials and mixtures A. Ya. Kalashnikova and Yu. D. Pozdnev (*Lit. Proizv.*, 1960, (9), 38–39) The NIILITMASh has worked out a method for determining the pH of the original moulding materials and mixtures by means of a pH meter type LP–5. This instrument consists of a special measuring unit, a two-valve, dc amplifier and a set of electrodes.

On veining tendencies of air setting core sands K. Horiuchi, T. Miyasaka, and A. Matsui (*Imono*, 1960, **32**, July, 469–474) The factors producing or eliminating veining in air setting sands were investigated and tests in several binders were studied by measuring the properties of the sand at elevated temp. A summary of the results is presented.—S.H.-S.

Improvement of the stability of sand mould surface by starch additives H. Tanimura and S. Mukae (*Imono*, 1960, **32**, June, 438–445) The uses of α-starch, which is insoluble in water and swells remarkably, and of dextrin, which is soluble in water, are described in a series of tests and the results of their addition to synthetic sand moulds are discussed.—S.H.-S.

Method of calculating the dimensions of pipes for vibration sand slingers A. I. Gorskii (*Lit. Proizv.*, 1960, (8), 25–27) Two structural alternatives are given to obtain the required rigidity for these pipes; the tightening rods are set at an angle to the pipes under vibration. The calculation resolves itself into determining the natural frequency as compared with the imposed frequency of oscillation, and the important factor here is the non-uniformity of the moulding mixture in the pipe. An expression for this calculation is shown which gives results within 5·5–6·2%.

Feeding and solidification of vertical column G. Ohira and M. Koizumi (*Imono*, 1960, **32**, June, 416–428) A test to find the movement of molten Al in a vertical column as well as its feeding and solidification is described and the results are presented.—S.H.-S.

Gating and feeding of small steel castings A. Pearson (*Found. Trades J.*, 1960, **108**, June 23, 779–786) Principles are restated and practice in the author's foundry illustrated in great detail. Exothermic aids are described and the importance of atmospheric cores is discussed.

Exothermic risering effects on properties of cast armor steel J. M. Ingraham (*WALTR*–616.1/1; *PB* 161698, 1960, June, pp.35; from *US Rec. Rept.*, 1960, **34**, Sept. 16, 326) This is a limited study of the effects of the use of exothermic riser sleeves on the physical and mechanical properties of a cast armour test plate. The work reported herein consists of studies to determine hardness, macro- and microstructure, tensile, and impact properties in areas adjacent to and removed from the riser area.—C.F.-C.

Risering of steel castings H. F. Bishop (*Foundry*, 1960, **88**, Sept., 116–123) This article, the second of three on the risering of steel castings, explains how to calculate the proper size for a riser, and chills and the beneficial effects they have on feeding range are discussed.—S.H.-S.

Bentonite clay of the far North-East A. A. Svarika (*Lit. Proizv.*, 1960, (10), 40–41) Reference is made to the article by A. L. Tumanskii and A. Ya. Kalashnikovaya in *idem.*, 1960, (4) 'Bentonite clays of the USSR'. Svarika adds another source of bentonite to the list: the Pervomaiskii region in the Magadanskaya Oblast. Quality of the raw material and supplies are good.

The bonding mechanism in foundry sand mixtures D. C. Williams (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 269–271) A discussion of the mechanism is followed by a compounding procedure designed to give the desired properties in the foundry sand, using the most economical quantities of bonding agents.

Influence of the grain size and mineralogical composition of foundry sands on their behaviour in production F. Hoffmann (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 263–268) Details are given of experiments carried out by George Fischer Ltd, Schaffhausen, Switzerland, on the influence of grain size and shape of sands on their behaviour during moulding and casting. The influence of mineralogical–petrographical differences on the properties of moulding and core sands in the green condition and during processing, and on their behaviour at elevated temp. are examined.

Continuous sand preparation N. Öhnbom (*Gjuteriet*, 1960, **50**, (8), 107–109) A description of the Pekay and Junkerath sand mixers.

Some aspects of steel foundry sand control A. P. Bagchi (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 241–245) Factors in the choice and control of sands and binders, the formulation and testing of sand mixtures, and sand preparation, are discussed with reference to TELCO practice.

The influence of pore size on some properties of foundry sand J. H. Gittus (*Iron Steel*, 1960, **33**, Aug., 429–433) A method is developed for computing the average intergranular pore size of foundry sands from a knowledge of its grain size distribution. Thermal conductivity, gas permeability, and resistance to metal penetration were calculated from this value for a number of sands, and results agreed well with experimental results.

The properties and behaviour of clay bonded sands at high temperatures W. B. Parkes (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments in Foundry Technology*, 1958, Feb. 5–8, 253–262) The effect of heat on the constituents of sand used for green sand moulding are first outlined, and the influence of heating rate examined. A series of experiments to investigate the effect of expansion at high temp. on the incidence of casting defects is described, and measures to eliminate such defects are discussed.

A device for determining the strength of moulding mixtures D. M. Litvin and E. I. Mart'yanov (*Lit. Proizv.*, 1960, (10), 45–46) The conventional instrument for determining the strength of a green mixture has a manual drive which makes it impossible for a constant rate to be maintained. In addition it is tiring to use the machine for many measurements and the readings are unreliable. These disadvantages are overcome in the new table instrument which is described.

Nuclear unit detects moisture in foundry moulding sand H. A. Burley and M. J. Diamond (*Iron Age*, 1960, **185**, June 16, 124–125) A system for measuring the average moisture content of a batch of foundry sand using a 'nuclear gauge' is described. A fast-neutron source of ^{239}Pu and Be is driven down a tube into the sand, and slow neutrons produced by collision with H nuclei are counted on two detectors. The amount of water to be added to give the required moisture content is read off on a dial.—D.L.C.P.

How moulding sand moisture affects casting quality J. S. Schumacher (*Foundry*, 1960, **88**, Aug., 70–74) Variable factors in moulding sand produce important changes in casting quality. A study of moisture content and its effects on moulding sand properties are tabulated and reported.—S.H.-S.

A method of producing pouring systems for casting parts in graphite moulds M. A. Savidov and E. A. Merkulov (*Lit. Proizv.*, 1960, (10), 41) The new method has been introduced at the Stankolit works. One casting produces eight blanks of high strength and surface purity (they can be used almost without machining). The moulds are easily made from artificial graphite and are very durable. The new process results in considerable savings of steel and pig iron.

Critical investigation of various gating systems for sand moulds C. Trenckle (*Giesserei*, 1960, **47**, Sept. 22, 519–526) Design systems and methods of calculation are examined in detail (28 refs).

Water model test for the gating system of marine propeller casting. I. On the sprue base and the effect of a 2nd sprue. II. On the runner and ingate M. Kanamori, S. Ueda, and H. Sakaguchi (*Nippon Kinzoku*, 1960, **24**, (2), 67–70; 71–74) I. Model tests, using water in plastic, show that the design of sprue base is important in avoiding intense agitation of the flow, and the use of a second sprue decreases the flow and washes away trapped air. II. Flow properties are compared in tapered and U-shaped runners and runners with an attached damper box and single- or multiple-hole ingates. The 'pre-filling' method of pouring greatly reduces agitation and aspiration, and washes away trapped air quickly.—K.E.J.

Casting of ingot mould halves, thick plates, flanges etc. in cast iron using a 'set' riser J. Scholz (*Giessereitechn.*, 1960, **6**, Oct., 311) The author of the short note calls this modification of a riser a 'Setzsteiger' or set riser. This is a riser that is displaced by 2/3 of its dia., so that only 1/3 is in contact with the casting, thus eliminating gating and obtaining a strong sucking action. It can easily be knocked off, but the knock must always be towards the casting, otherwise the casting will be damaged.

Principles of risering with reference to steel castings P. K. Sandell (*Indian Construction News, Special No.*, 1958, **7**, Nov.; *Proc. Symposium on Recent Developments on Foundry Technology*, 1958, Feb. 5–8, 143–153) Subjects discussed include feeding efficiency, consideration of hot-spot or Heuver's circles, solidification times of risers and castings, thermal analysis of solidification process, feeding range, riser casting connections, knock-off cores, and the relation of the dimensions of the core opening to its functional ability. The concept of the 'incandescence ratio', i.e. the proportional increase in freezing time resulting directly from the incandescence of the core, is developed (18 refs).

Risering of steel castings (Part I) H. F. Bishop (*Foundry*, 1960, **88**, Aug., 75–79) The first of three articles on the risering of steel discusses two basic problems involved in the correct risering of steel castings, (1) riser location, and (2) riser dimensions.—S.H.-S.

Reducing the volume of risers for cast steel components by means of exothermal jackets C. Stefanescu and V. Marinescu (*Met. si Constr. Masini*, 1960, **12**, (4), 285–294) Experiments are described to establish the optimum exothermal mixture and the optimum dimensions of the risers, and some experimental castings are described. The mixture consists of (in % of weight without binder or water) Al powder 10, scale 62, Fe–Si (75%) 13, Chamotte 8, clay 7. Plus binder (sulphite liquor, dextrin or waterglass) 5, water 1. Granulation of components from 0·1 to 5 mm. A specification is given of the type of jacket corresponding to the different castings and a nomogram for the selections of suitable dimensions.

The design of 'saving-risers' P. Németh and I. Lipovetz (*Koh. Lapok-Öntöde*, 1960, **11**, Feb., 32–36) The design and use of 'saving-risers', i.e. exothermic risers and pressure risers are described.—P.K.

Experience on the production of steel-casting accessories with a high grog content D. S. Rutman and L. V. Vinogradova (*Ogneupory*, USSR, 1952, **17**, 22 ff; *SLA* 60–13951; from *US Tech. Trans.*, 1960, **3**, June 24, 801) No abstract.—S.H.-S.

The use of chromium–magnesite powder in the manufacture of moulds for high-manganese steel G. I. Yankelevich and G. N. Rezhichenko (*Lit. Proizv.*, 1960, (10), 44) Experience at the Magnitogorsk combine is described. Chrome magnesite powder is now used instead of chrome–iron ore (chromite). The surface quality of the castings is improved and there is a considerable saving from the difference between the prices of the two materials.

Pearlite stringers in black-hearth malleable cast iron (*Fonderie*, 1960, Aug., 343–345) It is pointed out in this paper that pearlite stringers are not necessarily due to surface oxidation during annealing.—B.P.

Shrinkage cavities and porosity in grey cast-iron castings J. Bradík (*Slévárenství*, 1960, **8**, (9), 301–304) Factors influencing the occurrence of shrinkage voids and cavities are surveyed in the light of the recent literature and researches in Czechoslovakia. Procedures best suited for tracing the cause of such faults, and methods for preventing them are discussed.

Internal defects in steel castings J. Cameron and J. Courtney (*Foundry Trade J.*, 1960, **109**, Sept. 15, 333–336; from *W. Scotland ISI* preprint) The original paper is condensed. Defects due to the mechanism of solidification, to gas, to deoxidation practice and to intergranular fracture are outlined and the methods of avoidance are indicated.—C.V.

The application of the vibration process in the production of cast steel A. A. Romanov (**Cast Steel in vibrating moulds*, National Scientific and Technical Publications for Mechanical Engineering Literature, Sverdlovsk, 1959, Oct.) A translation from German from a Russian original.

Scarfing of medium alloy Cr–Ni steel castings with the oxy-acetylene burner and the carbon electrode K. Mazanec and L. Huvar (*Slévárenství*, 1960, **8**, (10), 347–350) An experimental study showed that both methods are suitable

for the removal of defects. Subsequent welding-in must be done with 18/8 electrodes.—P.F.

The control of castings by standardization J. Gélain (*Fonderie*, 1960, May, 201–203) A note on the use of statistical methods of quality control.

VACUUM METALLURGY

Vacuum steelmaking A. M. Samarin (*JISI*, 1961, **198,** June, 131–141) [This issue].

Electrical supply and régime for vacuum arc furnaces L. N. Belyanchikov, R. N. Grigorash, and A. V. Panov (*Izvest. VUZ Chern. Met.*, 1960, (2), 39–46) A summary setting out the considerations governing the selection of the current for vacuum arc furnaces having regard to the composition of the melt. Russian and foreign practice are compared.

The temperature of the metal when melted *in vacuo* with the electric arc L. N. Belyanshikov, R. N. Grigorash, and A. V. Panov (*Izvest. VUZ Chern. Met.*, 1960, (2), 32–38) The metal is overheated relatively little with this method. The temp. of the metal bath when melted *in vacuo* with an electric arc is determined chiefly by the temp. of fusion.

Low temperature metallurgy: vacuum as an inert atmosphere A. S. Darling (*Metallurgia*, 1960, **62,** Nov., 187–191) Topics discussed are: the gas-tightness of a vacuum system, contamination during the vacuum melting of iron, nickel, etc., and vacuum oxidation processes in the solid state.

Experimental vacuum casting of transformer steel M. Markuszewicz, H. Zak, and J. Groyecki (*Prace Inst. Hutn.*, 1960, **12,** (4), 167–179) Experiments were carried out, one casting being poured in air and one *in vacuo*. Chemical compositions, macrostructures, and magnetic properties were investigated. The latter in heat-treated and cold rolled samples. The results were as follows: vacuum casting decreased gas content and improved ingot structure, ingots were sound and without blowholes even when the gas content of the melt was high, and no magnetic effects due to vacuum casting were observed.

The design of high-temperature furnaces using graphite elements E. M. Haines (*Industrial Carbon and Graphite*, 1958, 481–490, reprint) Details of vacuum and intert-atmosphere furnaces are given.

Improvement of the tensile strength of Fe–C–Si system alloys by vacuum-melting. Vacuum-melting of cast iron (Rept.2) I. Iitaka and M. Kikuchi (*Waseda Univ., Rep. Casting Res. Lab.*, 1959, Dec., 1–6) The authors had the intention of clarifying the effects of very small amounts of gaseous elements or non-metallic inclusions contained in cast iron. In order to eliminate the gaseous elements or inclusions from molten iron, a vacuum-melting procedure was adopted.—C.F.C.

REHEATING FURNACES AND SOAKING PITS

Increasing the productivity of soaking pits G. L. Nosov, B. I. Kitaev, V. E. Burkser, N. K. Ryabokon', and V. V. Shalaev (*Stal'*, 1960, (12), 1141–1145) Charging hot and improving the power of the heating units with better organization can increase productivity. Trials pointing in this direction are described.

The THERMO-designed billet reheating furnace M. Shobu and K. Asada (*Suiyokwai-Shi*, 1958, **13,** Sept., 487–492) An account of the reheating furnace for the continuous wire rod mill at Kobe constructed by Thermo-Industrie Ofenbau G.m.b.H. The various advantages of the design are set out.

Technical and economic comparison of gas and induction heating for forgings H. Schaefer and H. Ruch (**Praktische Energiekunde*, 1959, **7,** (2), 107–141) Ways of economizing in both are described. The costs of induction heating were always higher, though various imponderables are in favour of the method.

New forge furnace at BISRA (*Process Control. Autom.*, 1960, **7,** Sept., 441–442) The new experimental fully instrumented forge furnace installed in the Energy Section of BISRA at Battersea, London, with a brief statement of its functions and details of its equipment, is described.—S.H.-S.

Combined town gas/fuel oil flames for heating ferrous metals E. A. K. Patrick and N. G. Patel (*Gas Council Res. Commun.*, 1960, **GC 67,** pp.25) The effect of varying types of fuel (fuel oil, town gas, and various mixtures of fuel oil and town gas) was studied at differing excesses of air, times of heating. Adherence of scale formed on mild steel and alloy steels is reported on and the decarburization of steel surfaces is studied. The results have not shown that the combined flame offers any marked advantage in its effects on ferrous metals, it has been found that town gas can possess a marked advantage over fuel oil if the level of excess air in forge furnaces is held below 10% in order to achieve thermal efficiency. This effect is largely a function of the S-content of the fuels.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Composition adjustment considerations for protective gas composition control W. Röver (*Stahl Eisen*, 1960, **80,** Dec. 22, 1955–1963) The author discusses the principles of protective gas production, the reactions involved, the selection of the best point of sampling the gases, the errors that may occur in measuring the composition of protective gases, and the causes thereof. This is followed by descriptions of control equipment for composition adjustment of the protective atmosphere.—T.G.

A new instrument for the direct determination of the carbon potential of furnace gases T. Schmidt and J. Wünning (*Stahl Eisen*, 1960, **80,** Dec. 22, 1952–1954) An instrument is described that allows measurement of the carbon potential of furnace atmospheres directly by means of the electrical resistance of an iron wire. The effect of temp. on the resistance of the wire has been eliminated by electrical means. Using mild steel wires, as has been done so far, the carbon potential can be measured only at temp. above 900°C, but it is expected that wires alloyed with Mn or Ni will extend the useful range of the instrument to lower temp.—T.G.

Experiments in regulation of gaseous atmospheres. II R. Chatterjee-Fisher and O. Schaaber (*Härt. Techn. Mitt.*, 1960, **15,** Oct., 134–140) The carrier gas composition and coking atmosphere of a plant using an endothermic single-stage generator were examined by physical means. Dew-point and CO_2 content are shown to be of importance with regard to coking behaviour. A dew-point regulator for an endothermic generator is described.

Heat-treatment of cast iron piston rings B. Ciszewski and P. Bukowski (*Przeglad Mechaniczny*, 1959, (12), 406–497; from *Polish Tech. Abstr.*, 1960, (37), 47) A description is given of the two common methods of heat treatment for increasing the hardness of piston rings; normalizing annealing based on heating at a temp. of from 850° to 900°C for 1–2 h, then cooling in air, and hardening and tempering to a given hardness applicable only to high-grade cast iron. Heating is done in a salt bath at a temp. of 870°C with cooling in oil.

Ionic cementation of steel V. S. Vanin (*Izvest. Akad. Nauk. Otdel. Tekhn. Met. Toplivo*, 1960, (3), 66–69) It has been demonstrated experimentally that results obtained by cementation above the level of the liquid medium, in its vapours, are satisfactory. The possibility was thus disclosed of heating specimens not only by resistance but also by high-frequency currents or by excitation from glow discharges. Tests carried out with cementation in glow discharges gave good promise because of the simplicity of the installation and the economical manner of the operation.

The heat-treatment of carburizing steels F. P. Heard (*Trans. Austral. Inst. Met.*, 1954 and 1955, **7–8,** 305–311) Selection of steels from grades commonly used in Australia and their heat-treatment for optimum machinability as well as the carburizing process, especially gaseous carburizing, are discussed.

'Homocarb' furnace retort unit: Use of Incoloy DS (*Wiggin Nickel Alloys*, 1960, No.57, 5–7) These gas-carburizing furnaces (1·9 to 40 ft³) are described; they are vertical and cylindrical in shape, resistance-heated and charged and discharged from the top. The outer steel body is lined with a refractory carrying the resistance heating elements while a cylindrical retort contains the carburizing atmosphere out of contact with the elements. A fan ensures constant circulation. A C-bearing liquid is metered into the furnace at the top and is cracked just beneath the lid. Operating temp. 870–940°. The furnace is fabricated from Incoloy DS heat-resisting alloy sheet, ¼ in thick welds being made with Inco-Weld A electrodes. The sand seal trough is now pressed in Incoloy DS and joined to the main body. This alloy is 36–39%Ni and 17–19%Cr, has good oxidizing resistance, and in reduction can even be used up to 950°. It is specially resistant to a carbonaceous atmosphere and to 'green rot'. 'Vapocarb' furnaces, using lower carbon potential to give protection against oxidation and not a carburized case, are also described. In other respects they are similar.—C.V.

Surface hardening of titanium by chemical and thermal treatment A. V. Smirnov and A. D. Nachinkov (*Metalloved. Term. Obra. Met.*, 1960, (3), 22–29) Nitriding by pure nitrogen or nitrigen at low pressure is applied more widely than other methods. Ammonia has no advantages over nitrogen as it gives rise to simultaneous saturation of the metal with hydrogen. Cementation may be carried out with powdered carbon (graphite, soot) *in vacuo* or in an atmosphere of argon with addition of propane or methane, but in this case the layer of TiC will be thin (only about 7·5 μ), and it must be remembered that the metal can be saturated by hydrogen originating from the dissociation of the hydrocarbons. In boriding, just as in cementing, a good covering with the titanium boride layer is observed with a small thickness of the order of 10 μ.

Flame hardening gears S. D. Heron (*Met. Prog.*, 1960, **78,** Sept., 130) A letter. Early experience in the flame hardening of gears in England is described.

Improving the mechancial properties of 65G spring steel A. V. Semichastnaya (*Stanki Instr.*, 1960, (8), 29–31) Isothermal hardening increases the mechanical properties of this spring steel in comparison with the usual hardening by quenching in oil and tempering. For equal hardness the UTS is greater by approximately 19%, the yield point by 11·7%, and the limit of proportionality by 10%; isothermal treatment followed by shot peening increases the strength of the spring owing to the increase of 5–10% in the modulus of tangential elasticity.

A new Wild-Barfield AHF induction heating generator (*Wild-Barfield J.*, 1960, **7,** June, 6–7) A new 2½ kW generator is described in detail. Its specification is added.—S.H.-S.

Induction hardening of cast iron cylinder castings (*Iron Steel*, 1960, **33,** Oct., 512–513) A method of radio frequency induction heating, developed by Sheepbridge Stokes Ltd, and its application to the hardening of the inner surface of centrifugally cast iron liners are described.

A new general purpose induction hardening machine (*Wild-Barfield J.*, 1960, **7,** June, 10–11) A machine capable of handling a wide range of components and increasing the possibility of using induction hardening on batch production work is described, and illustrated with speed reduction unit in position.—S.H.-S.

Induction hardening crankshafts with Electherm equipment P. A. Sidders (*Machinery*, 1960, **97,** Aug. 3, 263–266) Crankshafts for small high-speed diesel engines are hardened by semi-automatic electric induction equipment. Interchangeable inductors for different shafts are available. Four shafts, each with three journals, require 11½ min for the complete operation. Case depth 0·080 to 0·120 in. Hardness 60/62 RC. Shafts are tempered at 180°C in a tunnel furnace.

Recrystallization diagrams for induction heating M. N. Bodyako, Yu. M. Loiko, B. L. Pavlyukevich, and V. I. Parkhimovich (*Metalloved. Term. Obra. Met.*, 1960, (1), 49–52) The following annealing schedule may be recommended for the materials investigated (a) for technical iron: heating to 1000° at 50°/s or to 1100° at 200–650°/s and for 1Kh18N9T steel, heating to 1200° at a rate of 60–60°/s. These schedules for a minimum grain size, ensure the formation of a completely

recrystallized structure for all degrees of deformation.

Experimental determination of depth of hardness in induction hardening at a frequency of 10 kcs H. Geisel (*Elektrowärme*, 1960, **18**, Oct., 309–313) In induction hardening only the surface of the material is immediately affected by the heat generator. This is due to a skin effect and enables the depth of hardness or case to be varied as desired, the maximum depth being governed by the material being hardened. Using two theoretically calculated graphs, the necessary power input and the heating-up time can be determined, provided that hardening temp. and depth of hardness are known. Two further graphs show the correlation of flux density and depth of hardness in hardening cylindrical samples of Ck 45 of varying dia. The frequency selected was 10 kcs. The graphs were plotted after evaluation of extensive hardening tests.—S.H.-S.

Effect of the jacket dimensions of the induction furnace on its elec.rical parameters N. I. Bortnichuk and I. P. Brukovskii (*Vestnik Elektroprom.*, 1960, (8), 27–30) In the construction of electric furnaces with a non-magnetic steel jacket the jacket dia. is usually taken at 2·5–3 times the dia. of the inductor. At these dimensions its effect can be neglected. In cases when the jacket must have smaller dimensions this is no longer so. A theoretical analysis of such cases leads to an equation by means of which the effect of the jacket is corrected by varying the number of turns on the inductor and altering the capacity of the condenser battery.

Boriding electroplated steel V. D. Taran and L. P. Skugorova (*Metalloved. Term. Obra. Met.*, 1960, (1), 2–5) The boriding of electroplated steel with different types of plating is not uniform. On nickel-plated specimens a borided layer of normal structure is obtained. A copper skin on the surface of the specimens promotes diffusion of the boron into steel and may serve as a local protection of non-working surfaces from boriding.

Vapour boriding in a medium of boron trichloride M. A. Pchelkina and Yu. M. Lakhtin (*Metalloved. Term. Obra. Met.*, 1960, (7), 40–42) The possibility of boriding in a medium of BCl_3–H_2 at 700–750° has been demonstrated. The schedule recommended is: 850°; holding time 3–6 h; the ratio between BCl_3 and hydrogen must be about 0·05. With an increase of the carbon content in the diffusion layer, less FeB forms and the hardness of the FeB and FeB_2 phases diminishes.

Saturation with sulphur of the surface of components of ferrous metals in hydrogen sulphide and hydrosulphide solutions N. A. Solov'ev (*Metalloved. Term. Obra. Met.*, 1960 (1) 47–48; *Patent No.*107073) The method here explained of saturating the surface of ferrous metals in aqueous solutions of H_2S increases appreciably their resistance to scoring. The additional treatment of the sulphided surface in dichromate solutions improves their anti-corrosion properties.

Sulphiding and the properties of the sulphided metal A. V. Kriulin (*Metalloved. Obra. Met.*, 1960, (7), 31–40) Investigations carried out by the author regarding erosion, over 50 h with high loads ($PV = 50$ to 100 kgm/cm²/s) of steel and iron specimens, sulphided in baths of different composition, have shown that the most effective reduction of the erosion of rubbing surfaces is achieved in baths in which the saturation of the metal surface by sulphur, nitrogen, and carbon proceeds simultaneously. It has been demonstrated that the simultaneous action of these three elements imparts high resistance properties against wear. Sulphiding alone (saturation of the surface with sulphur) for increasing resistance to wear is advisable only for iron cermets components.

Phosphatization treatment as a means for increasing resistance of cutting tools D. Nita and V. Berceru (*Met. Constr. Masini*, 1960, (7), 640–643) The process is based on the reaction taking place in a bath containing H_3PO_4 in water at 95–97°, into which the completely degreased tools are introduced after their last finishing operation. The reaction mechanism is as follows: $Fe + H_3PO_4 \leftrightarrows Fe(H_2PO_4)_2 + H_2$; $Fe(H_2PO_4)_2 \leftrightarrows FeHPO_4 + H_3PO_4$; $3\,FeHPO_4 \leftrightarrows Fe_3(PO_4)_2 + H_3PO_4$. In this process the surface is transformed partially into iron phosphates and the insoluble phosphates are then eliminated leaving a crystalline phosphate layer. Detailed descriptions are given of the preliminary investigations and further study is recommended.

The kinetics of the decarburization of ball bearing steel during heat treatment N. P. Zhetvin, L. N. Podvoiskii, and L. I. Krylova (*Metalloved. Term. Obra. Met.*, 1960, (2), 37–42) In ShKh9 steel heated up to 740° with a holding time of 16 h either in an oxidizing medium or in a tube filled with fresh iron chips, decarburization does not occur. This refers to the metal covered with scale and also without scale. The decarburizing processes occurring above 740° intensify with time. On machined specimens in an oxidizing medium decarburization begins at 760° after 8 h, at 780° after 4 h, at 800° after 2 h, and 820° after 1 h. On specimens covered with scale and decarburized on the surface at these temp., a small (up to 0·18%) increase in carbon content is observed due to the diffusion processes which take place.

Continuous annealing of centrifugally cast iron pipe J. Beaque (*Met. Treating*, 1960, **11**, Oct.–Nov., 12–15) The author describes, with illustrations, the 30 t/h continuous annealing plant recently installed in the Iowa works of Griffin Wheel Company. The plant handles pipes of up to 20 ft long and 12 in dia. and the burners capacity is 30 million Btu/h.—A.H.M.

Annealing line added to U.S. Steel's Pittsburgh Works (*Blast Furn. Steel Plant*, 1960, **48**, Sept., 950–951) The continuous annealing line described, for annealing steel strip up to 38 in at up to 1500 ft/min, has been installed in the Sheet and Tin mill.

Conveyorized, radiant furnace heats 6000 lb an hour R. E. Buckholdt (*Steel*, 1960, **147**, Sept. 12, 128–129) The operation of a walking beam furnace at the Melrose Park (Ill.) Works of International Harvester Co. is described, with details of functions, heating controls, and production economics.—S.H.-S.

Open coil process shows way to gas alloying J. Arnold (*Iron Steel Eng.*, 1960, **37**, Aug., 91–111) A detailed account of this process and its applications. In the open coil process the coil is wound loosely, and the wraps spaced by inserting nylon string or a metal tape. In this way heat and gases can come into uniform contact with the whole of the coil surface. Several applications are described.

Flexible furnace stress relieves large fabrications (*Metalw. Prod.*, 1960, **104**, Aug. 17, 59–61) The stress relieving of large or long welded fabrications, by means of heating nuts composed of ceramic bands threaded on nickel-alloy resistance wire 'hair-pins' linked together to provide a series of electrical circuits capable of giving a maximum mat surface temp. of 1000°C, which are flexible and can be bent to a minimum radius of 1in, thus constituting, with superimposed prime lagging, a 'flexible' furnace,' is described.—S.H.-S.

Low temperature annealing of strands for prestressed concrete structures L. A. Krasil'nikov and V. A. Chertousov (*Stal'*, 1960, (12), 1146–1149) Annealing conditions for cold-drawn rods are established and a sodium nitrite salt bath is shown to be suitable. Induction heating is, however, even better.

The second anneal of E 45 and E 46 transformer steel V. V. Druzhinin, G. A. Zykov, and M. I. Nekrasova (*Vestnik Elektroprom.*, 1960, (5), 41–43) The standard schedule for the second anneal does not restore the magnetic induction to the level it had after the initial anneal. To secure this and to obtain a further increase in the magnetic induction in weak fields, it is necessary to carry out the second anneal in an oxidizing medium followed by slow cooling. For the steels mentioned, the following schedule is recommended: heating to 750° and holding not less than 2 h, cooling in the furnace to 450°, holding 15–20 h at that temp., and subsequent cooling in the furnace.

Examination of the speeded-up heat treatment of precision steel castings by the investment method A. L. Belinkii and A. A. Shchennikova (*Metalloved. Term. Obra. Met.*, 1960, (7), 55–57) The prolonged anneal of 45 L and 25 L steel castings does not confer any advantage as compared with normalization. A high heat tempering of investment castings after normalization does not produce any appreciable reduction of hardness nor any extra improvement in mechanical properties. The recommended schedule for 45L and 25L steels is normalization from 870° holding the charge 45 min at this temp.

The heating time of components in salt baths E. A. Smol'nikov (*Metalloved. Term. Obra. Met.*, 1960, (2), 53–58) The calorimetric investigation may be used for determining the time necessary for heating right through components of intricate form. A mathematical treatment of the experimental data confirms the existence of a relation between the time necessary for the through heating of the component of simple shape and its characteristic dimensions. This relation is expressed by a function of degree with indices $b > 1$. The value of the coefficient of shape has made possible the determination of corrections in the time of heating, by taking into account the shape, and in this way it renders the calculation more accurate.

Heat treating large steel castings T. Ditchfield and R. Waite (*Met. Prog.*, 1960, **78**, Sept., 93–96) The use of direct-fired radiant gas burners in maintaining a uniform furnace temp. and hence closer control of the operation is described.

Influence of controlled partial austenitization on the structure and properties of quenched alloy steels K. Winterton and J. Carruthers (*Can. Min. Met. Bull.*, 1960, **53**, May, 336–342) Two methods are described which have been tried to induce partial austenitization. (A) a dc resistance heating method involving rapid entry into the austenite field: (B) a new method, described as the 'threshold technique', involving homogenization of temp. just below A_1, followed by entry into the austenite field; for which the last two furnaces are required. Resulting structures have been examined for microstructures, hardness, tensile, and impact values, and the results are described and discussed.—S.H.-S.

Heat treating anti-aircraft rifles T. A. Dickinson (*Met. Treating*, 1960, **11**, Oct.–Nov., 26–27) A brief description is given of vertical immersion salt baths, believed to be the largest in the world, where anti-aircraft gun-barrels weighing 1300 lb and of overall length 177in have been heat treated. The barrels were kept at 1575°F for 65 min then quenched to 500°F. The vertical immersion reduces the possibility of distortion at the high temperature during annealing.—A.H.M.

Efficient heat treatment of rolls for hot rolling M. P. Braun, O. S. Kostyrko, E. P. Dobryanskaya, and A. I. Kondrashev (*Metalloved. Term. Obra. Met.*, 1960, (2), 48–52) For many large forgings of 55Kh steel, isothermal holding immediately after forging is not beneficial. The most efficient schedules of heat treatment are those which take into account successive recrystallizations. A full schedule of heat treatment has been worked out replacing anneal with normalization, which shortens by 40% the duration of the operation for large components.

New alloys combine strength with ease of fabrication Jones & Laughlin Steel Corp. (*Iron Age*, 1960, **186**, Sept. 29, 124–125) New constructional steels, combining high strength, and welding and forming ease, after a 'restrained quench,' are described in a series of five, with a supporting claim that they can be bent without the possibility of cracking or failure.—S.H.-S.

The effect of the composition of quenching media on the hardenability and strength of carbon steels Yu. A. Geller and S. D. Vais (*Stanki Instr.*, 1960, (8), 27–29) Quenching in alkaline salt solutions has the following advantages among others over water; the hardness of the surface layer increases by 1–2 units; the hardenability and the thickness of the quenched surface layer increases; hardening temp. needed for good hardenability may be reduced; as a consequence overheating can be eliminated; the steel is of great hardness even in the 'as hardened' condition, and also after low tempering. Best results were obtained with aqueous solutions of NaCl (5–6%); NaOH

(10%), and $KMnO_4$ (4–5%). The latter gives a greater hardness but a thinner hardened skin.

Modern quenching techniques make it easier to heat treat steel (*Met. Prog.*, 1960, **78,** Oct., 101–111) [A Staff Report] The characteristics of the quenching media available are enumerated, and quenching equipment described.

Measuring quenching rates with the electronic quenchometer H. J. Gilliland (*Met. Prog.*, 1960, **78,** Oct., 111–113) This instrument developed by General Motors Technical Centre, Detroit, tests and compares quenching media under actual production conditions. It is an adaptation of the magnetic quench test (of ASM booklet 'quenching of steels') and makes use of the Curie point of an Ni ball (about 670°F).

Heat treatment of welded tools E. I. Malinkina (*Stanki Instr.*, 1955, **26,** (7), 29–29) A study of the cracking of quenched carbon and high-speed tool steels is reported with the tests recommended and preferred heat-treating procedures. Steels 45, U7, R9, and R18 were used, their compositions are given.

The effect of the temperature of water in aqueous solutions on crack formation during quenching Yu. G. Vyshkovskii (*Metalloved. Term. Obra. Met.*, 1960, (2), 32–37) The experimental findings confirm that preheating the water and the aqueous solutions increases the tendency to crack formation of medium carbon steels quenched for martensite. The high-carbon steels are sensitive to the preheating of the water only with a decarburized surface layer. The aqueous NaCl and NaOH solutions at the same temp. give a more uniform hardness and fewer cracks than water without any additions. These data refer to components of simple shape of a diameter between 5 and 15 mm.

Quenching wheels heated in a furnace, in a vertical machine L. A. Dolinskaya (*Metalloved. Term. Obra. Met.*, 1960, (2), 58–61) A machine is described in which a rail wheel, kept vertically with its lower edge slightly immersed in water, is rotated at different speeds for different periods of time. Experimental results, both after heating in the furnace and after induction heating, appear to show a number of advantages for this method of quenching.

Dry ice decimates die-quenching time A. Hegarty (*Metalw. Prod.*, 1960, **104,** May 18, 899–900) A process using dry ice to cool air blast to 40°F, thereby cutting cooling time to a tenth, is shown and described in use by the Ryan Aeronautical Co., USA. It is claimed that the time required for a cooling cycle is cut from 10 min to less than 1 min, and that the die in which the metal is chilled is kept at a low temp., permitting constant use. The construction of the die is given in detail.—S.H.-S.

Investigations on the kinetics of martensite tempering and of the decomposition of residual austenite by examining the hardness and the properties determined in the bend test of a steel containing about 1·1%C P. Fischer (*Arch. Eisenh.*, 1960, **31,** Oct., 617–622) Tempering tests were made in the range 160–400°C with times of 1 s to 136 h, and the hardness after tempering and the elastic limit, bend strength, and bend angle measured. The time and temp. effects on the hardness, if hardness was taken as the criterion of the state of tempering, indicated that increasing activation energies are found in association with decreasing hardness values, for attaining this state. The decomposition of the austenite mainly affects the elastic limit; the activation energy for this process was found to be 30 500 cal/mol (13 refs).

Cooling schedules for forgings from tempering temperatures A. A. Astaf'ev, A. A. Minasaryan, and A. I. Kondrashev (*Metalloved. Term. Obra. Met.*, 1960, (2), 42–47) The cooling of large forgings after tempering, either in air or in unheated pits results in high residual stresses. The optimum cooling after tempering schedule for forgings intended for high duty is cooling in stages: cooling in the furnace to 400°, and then in air. This reduces cooling time to one-third to one-quarter as compared with cooling in the furnace, and results in an acceptable level of residual stresses (up to 4 kg/mm²).

The effect of low tempering on the mechanical properties of 30KhGT and20K hN3A steels S. S. Khachaturov and G. N. Epshtein (*Metalloved. Term. Obra. Met.*, 1960, (7), 17–19) In tests with static bending, the plasticity of the material may be characterized by the value of the depth of the bending chord. The changes in this value with the temp. of tempering correspond with the changes in the impact strength of cemented specimens. Tests in static and dynamic bending of specimens of cemented 30KhGT steel have shown a fall of the impact strength in the region of a tempering heat of 180–280°. This fall in impact strength with static bending is not connected with the decrease in the maximum force at failure, and is only observable within the value of the depth of the bending chord. With 20KhN3A steel no drop in impact strength is observed, which is undoubtedly due to the reduction of the hardness of the surface layer and of the core of the material.

Short time tempering of high speed steels K. A. Malinina (*Metalloved. Term. Obra. Met.*, 1960, (3), 47–51) Some schedules are recommended. For small tools, two temperings at 600° for 15 min.; for medium and large tools, two temperings of 30 min at 580°. In mass production with two tempering containers available or with conveyor units, a first tempering for 20 min at 600° and a second, also for 20 min, at 580°.

FORGING, STAMPING, DRAWING AND PRESSING

Technical developments in modern drop stamps and forgings presses. J. S. Byam-Grounds (*Met. Treatment*, 1960, **27,** Oct., 415–421) The author deals with the factors governing the drop hammer, such as power, speed, and accuracy. A brief reference is made to steam, air, and hydraulic double-acting hammers, and the important design features of the drop stamp are discussed. The author concludes by an outline of future trends in hammer design.—A.H.M.

Hot forging in Russia—carbide inserts increase die life A. V. Pakhomov (*Metalw. Prod.*, 1960, **104,** May 4, 812–813) Hot-forging dies, fitted with Soviet VK 15 cemented carbide inserts at points of high wear are described, which are extensively used in the Soviet automobile and farm machinery industries. Electro-erosion and vapour blasting are used to machine and finish dies after the inserts which are an interference fit, have been assembled by freezing.—S.H.-S.

Elementary methods for the analysing of certain forging processes H. Lippmann (*Int. J. Mech. Sci.*, 1960, **1,** Jan., 109–120) Elementary methods of determining the pressure in plane strain press forging between dies with engravings of small inclination are given and it is shown, with the aid of an elementary model, how to compute the energy required in forging and the efficiency of the operation.—S.H.-S.

An upper-bound approach to plane-strain forging and extrusion. I H. Kudo (*Int. J. Mech. Sci.*, 1960, **1,** Jan., 57–83) An attempt to apply a method of load calculation used in certain plastic working operations to the analysing, in the form of an upper-bound approach, of plane-strain forging problems, with a claim that it offers a fairly accurate and simple means, as against the laborious analyses of forging and extrusion processes by slip-line field theory.—S.H.-S.

Study of the influence of surface defects on the long-range stability of crankshafts A. T. Wupperman, M. Pfender, and E. Amedick (*Report on a co-operative investigation of the Forging Committee of the Association of German Steelmen conducted at the Federal Institute for Materials Testing, Berlin*, 1958, pp.57) See *Stahl Eisen*, 1957, **77,** 1117–1122, for summary.

Forgeability of steels S. L. Gertsman (*Canad. Dept. Mines. Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 18–19) Torsion failure/temp. curves were constructed for 0·4%C and AISI 4340 steels, the optimum forging temp. being found. Similar trials on cast specimens are in progress.

Forging technology O. Kienzle and K. Lange (*VDIZ*, 1960, **102,** Aug. 21, 1155–1158) A review of the literature of 1959 dealing with this subject (64 refs).

Forging effects on the mechanical properties of three boron-treated steels E. DiCesare (*WAL TR* 312/80; *AD*–219749; *PB* 151814, 1959, July, pp.48; from *US Res. Rep.*, 1960, **34,** Sept. 16, 326) Steel alloys 14B35, 14B50, and 10R70 containing B and rare earth metals were hot-forged (2250°F) by upsetting and drawing (swaging) with reduction ratios up to 8 to 1 and 13 to 1, respectively. Longitudinal and transverse tensile and Charpy specimens, and micro and macrospecimens were tested and examined in the as-forged and in the heat-treated condition. Heat treatment resulted in optimum tensile properties and toughness in both the upset-forged and the drawn or swaged ingots, at approx. 66% reduction, for the swaged ingots, 50% reduction for the upset-forged 14B35 alloy, and 0% reduction for the upset-forged 14B50 and 10R70 alloys.

Steel for cold upsetting B. F. Guberman and F. M. Kerdman (*Stal'*, 1960, (12), 1150) A discussion of the article by Smol'yaninova and Shumakova (*Stal'*, 1959, (12)). The formulae there given apply only to small diameters and provide no general solution.

Influence of aluminium nitride on the forgeability of steels P. Bastien and P. Portevin (*Compt. Rend.*, 1960, **251,** Nov. 21, 2347–2349) The reduction in forgeability of steels as a result of the effect of additions of Al of between 0·0045 and 0·090% is studied in the range of 0·35%C steels. The characteristics of the phenomena are examined and the role played by Al is presented and discussed.

Explosive forming and chemical milling discussed R. C. Bertossa (*Met. Prog.*, 1960, **78,** Sept., 112–116) The mechanism and applications of explosive forming are discussed, and the use of chemical milling for the selective removal of metal is described with examples of its application.

Metal working with explosives J. Pearson (*J. Met.*, 1960, **12,** Sept., 673–681) A general review of the subject, dealing with sources of energy, the nature and action of the forces involved, and examples of explosive metal forming, powder compacting and forming, and explosive welding (32 refs).

High energy rate—its application to metal forming E. W. Feddersen (*J. Met.*, 1960, **12,** Sept., 682–686) Examples are given of explosive, hydroelectric, and pneumatic-mechanical forming, and reference is made to experiments on closed-cavity extrusion moulding, in which metal is forced in a semi-solid or plastic state through a small orifice into a closed cavity.

Response of metals to high velocity deformation—a report on the Estes Park conference J. B. Clark (*J. Met.*, 1960, **12,** Sept., 705–706) The conference was held in July 1960, at Estes Park, Colorado, for the purpose of reporting recent work dealing with the metallurgical effects produced by the passage of high-pressure shock waves through metals and alloys. Some of the papers are summarized.

Temperature distributions in some fast metal-working operations R. I. Tanner and W. Johnson (*Int. J. Mech. Sci.*, 1960, **1,** Jan., 28–44) The basic equations concerned with heat generation and flow in a plastically deforming body are discussed and criteria established for neglecting body forces and accelerations. Examples are given of the determination of the approximate temp. distribution in some fast plane-strain extrusion processes, using graphical techniques. Some non-steady motion problems are mentioned.—S.H.-S.

Press tools—their design and essential characteristics J. A. Grainger (*Sheet Metal Ind.*, 1960, **37,** Oct., 729–741, 765) An analysis is given of the basic requirements for successful blanking; bending and forming; and drawing of sheet metal. An expression is given for calculating the size of a press for a given operation and the article is concluded by some comments on the use of the double-action press for compound work.—A.H.M.

Heavy stamping presses now manufactured in Australia Vickers Ruwolt Pty. Ltd. (*Commonw. Eng.*, 1960, **47,** June 6, 42–45) New machine tools and other facilities installed by Vickers Ruwolt Pty. Ltd, Melbourne, for production of American-designed 'clearing' heavy press equipment, especially for large scale production of motor bodies, are described, with examples.—S.H.-S.

Simca mechanize for 1000 cars a day D. Scott (*Metalw. Prod.*, 1960, **104**, May 4, 817–820) The fastest-growing manufacturer's plant in France, at Poissy, 25 miles west of Paris with an output of over 1000 cars a day, is briefly described.—S.H.-S.

A 1000-ton rapid forging press powered by direct pumps P. Roux (*Mécan. Electr.*, 1960, **44**, Nov., 84–88) The equipment and operation of a 1000-t Morane press, with its method of installation and control are described and illustrated, with charts showing its time-economy and elasticity of operation.—S.H.-S.

Some aspects of the development of testing methods for the formability of sheet G. de Witte (*Sheet Metal Ind.*, 1960, **37**, Aug., 565–571) This paper was given as an introduction to the sessions of a recent meeting of the International Deep Drawing Research Group. The author deals with such general aspects of formability as the definition of 'specific' and 'general' formability; the discriminatory power of a testing method; the analytical approach and the problems of sampling and press-shop interpretation.—A.H.M.

Production procedure at the Beacon Works of Motor Pressings Ltd E. Thompson and C. R. Thompson (*Sheet Metal Ind.*, 1960, **37**, Oct., 718–728) A detailed and fully illustrated article describing the production processes of wide range of products such as washing-machine bowls, suspension struts for BMC Mini-cars, and the MG front suspension member. This article is the first of a series.—A.H.M.

Fundamental aspects of deep drawing and pressing T. L. Richards (*Sheet Metal Ind.*, 1960, **37**, Aug., 587–592) The author starts by describing the slip process in single crystals and gives a simple description of a dislocation. The deformation of polycrystalline material is then described, particular reference being made to work hardening and preferred orientation. The paper is concluded by a consideration of the effect of annealing on cold worked metals.

Deep-drawing with three dies H. W. Schulze (*Metalw. Prod.*, 1960, **104**, May 25, 940–941) An operation is described in which, pre-warmed by infra-red lamps, 36in dia, 12 gauge steel blanks are subjected to a 14in draw on a 750-t cleaving press to form washing machine tubs. Two other dies on the same press reverse-draw, trim, and pierce the tub.—S.H.-S.

New concepts of drawability of steels R. L. Whiteley and D. J. Blickwede (*Met. Prog.*, 1960, **78**, Oct., 74–75) The importance of steel sheet thickness in determining steel formability in certain types of pressing operations is discussed, with particular reference to die drawing.

Radial former halts scrap loss T. M. Rohan (*Iron Age*, 1960, **186**, Sept. 1, 70–72) A new unit, stretching parts for Atlas Missiles, in use at the Convair Astronautics plant new San Diego (Calif.), is described and illustrated in operation, with a claim to have cut scrap rate from 25 to less than 1% during the forming job. Various presses, containing vertically-mounted central dies with two retracting arms which can be angled from a straight 180° pull against each other to 90° or almost directly behind the die, are indicated as in common use across the US. Varied details of operations and advantages claimed are presented.—S.H.-S.

Mineral lubricants for deep drawing J. Versloot (*Metalen*, 1960, **15**, Nov. 30, 386–389) The author points out that many new metal processes have now been developed coupled with increased rates of production and the introduction of many different alloys, often resulting in the complication of lubricating problems. This is applicable particularly to deep drawing in that lubrication requires adaptation to the type of material being drawn as well as to the degree and speed of the process and the thickness. Drawing speeds range widely, from, say, 8 to 20 m/min for ferrous metals to 50 to 70 m/min for non-ferrous metals (copper, brass, aluminium, etc.). Cold drawing is the general rule, although some metals (e.g. Al) are sometimes, and Mg is practically always heated. Results are tabled of experiments conducted with mineral oils, mixed oils, emulsified oils, and fats, waxes, etc.

How to make better drawings and stampings P. G. Nelson (*Met. Prog.*, 1960, **78**, Oct., 85–95) The most suitable forming techniques, the most economical uses of the available grades of sheet steel, and the estimation of the stamping severity of a component before production are discussed.

Cold forming of steels F. Griffiths (*Machinery*, 1960, **97**, Dec. 7, 1315–1321) A general review. Some 35 examples are illustrated and the necessary equipment and processes are indicated. Equipment and lubrication are considered.—C.V.

The origin of the rippled appearance on cold-reduced deep-drawing steel K. Hill (*BHP Tech. Bull.*, 1960, **4**, June, 9–17) Investigation of defects in steel sheets led to the identification of Al additions as the cause, and the possibility of total elimination in being further investigated.

Machinery and tools for wire drawing and rope making works (*Wire*, 1960, April, 57—61) A description of some new designs shown at the 6th European Machine-Tool Exhibition, Paris, 1959.

The fundamentals of wire drawing C. P. Bernhoeft (*Wire Ind.*, 1960, **27**, Sept., 899–903) The third instalment of a book by the deceased author, being currently serialized each month in *Wire Ind.* Much of the information is of a general nature, with the addition of examples and statistics relating to Al, derived from special experience gained with that metal in the latter part of the author's career.—S.H.-S.

Bonderizing for wire-drawing (*Wire Ind.*, 1960, **27**, Sept., 881–883, 905) A review of the use of bonderizing in the wire industry, and some recent developments in its use as an aid to drawing and cold bending. A survey, briefly describing the production sequence, the properties of bonderite coating, advantages of strand bonderizing, cost economies in process time and thinner coatings, a new additive limiting coating weight, coatings for stainless steel, and speed limitations with oxalate coatings. Examples of German practice are adduced.—S.H.-S.

Cold extrusion of metals. Pt.VI. Under impact conditions M. T. Watkins and J. McKenzie (*NERL Plasticity Report*, 138, 1957, Oct., pp.42) Crank-press conditions were studied.

Production of steel pipes by extrusion Yu. M. Matveev and Z. E. Freinkman (*Stal'*, 1960, (12), 1122–1126) A review of practice in the USSR and elsewhere. The advantages of the process are noted and increased research and development is to be undertaken.

Cold extrusion of steel S. C. Poulsen (*Machinery*, 1960, **97**, Oct. 19, 876–886) Developments at the Royal Ordnance factory, Birtley, are described. Tool design and materials, typical extrusion operations, billet preparation, lubrication, cold extrusions, and cold drawing are discussed, examples and illustrations being given.—C.V.

Cold extrusion of ferrous and non-ferrous metals R. Tilsley and F. Howard (*Machinery*, 1960, **97**, Dec. 7, 1286–1293) Compositions of steels suitable for cold extrusion are given as well as those of tool steels. The pressures required for backward extrusion of non-ferrous materials are indicated. The pressures required for extruding C steel and stainless steel billets cold, and after preheating, are tabulated. The design of components for cold extrusion is discussed and sectional views of various special extrusion tools are given.—C.V.

Cold extrusion of small symmetrical and asymmetrical components O. May (*Machinery*, 1960, **97**, Dec. 14, 1375–1380) A mathematical approach is outlined in which the outside dia. of the total area upset can be calculated. The necessity for greasing and subsequent degreasing is stressed, and the relationship to braking action is examined while the necessity of mechanical braking is discussed. Thus as the flow resistance increases, the cross-sectional area of flow diminishes with the flow speed; consequently the speed of deformation plays an increasingly important part and it is pointed out that such phenomena proceed much more satisfactorily at a low speed of flow. Numerous examples are illustrated and discussed.—C.V.

Experiences in commercial production and application of cold-extruded components R. E. Okell (*Machinery*, 1960, **97**, Dec. 28, 1457–1460) A discussion of selection and design, choice of steels and preparatory treatments, and uses with special reference to flanged parts.

ROLLING MILL PRACTICE

54 Years of operation of the first electric driven reversing mill G. H. Krapf and E. I. Pearson (*Iron Steel Eng.*, 1960, **37**, Aug., 140–146) An account of the operation of a 30-in reversing mill installed in 1907 at the South Works of the Illinois Steel Co. (now United States Steel Corp.).

Maintenance in the steelplant: engineering maintenance S. Kraft (*Iron Steel Eng.*, 1960, **37**, Sept., 135–136) Steps taken to design equipment and facilities so as to minimize and facilitate maintenance in the new 80-in hot strip mill of the Great Lakes Steel Corp. Div. of National Steel Corp., Detroit, are described.

Standardization of lubricants for steel mills P. D. Metzger and H. D. Foster (*Iron Steel Eng.*, 1960, **37**, Sept., 178–182) A description of the mill lubrication standardization program carried out by Wheeler Steel Corp., which has resulted in an overall saving of at least 10% on large volume lubricants.

A study of deformation in oblique beam roll passes P. I. Polukhin and O. S. Popov (*Stal'*, 1960, (12), 1108–1112) This method of rolling with diagonally arranged joints is found to be suitable, especially for lightened, thin-webbed, and certain wide-flanged beams. Factors affecting stresses and power conditions are indicated.

Experimental analysis of tandem mill control equations H. Gill (*Inst. Mech. Eng.*, 1960, Aug., 3–13) A paper, discussing, with an experimental analysis, tandem mill control equations as developed by Hessenberg and Jenkins. The object was to investigate conditions of maximum inherent stability of a 3-stand model scale mill as a whole unit. Results are discussed in detail and conclusions drawn for optimum performance.—S.H.-S.

Is 'thinking' computer the key to automatic mill control? C. L. Kobrin (*Iron Age*, 1960, **186**, Sept. 15, 166–168) The installation of computer control in US Steel's Gary, Ind., works, its functions, prospects, and ability to classify and control products is described, and the general industrial attitude towards automation discussed.—S.H.-S.

An introduction to the theory and practice of flat rolling C. W. Starling (*Sheet Metal Ind.*, 1960, **37**, Oct., 755–765) An historical introduction is given of the rolling process which is followed by a description with many illustrations of the typical mills in use at the present time.—A.H.M.

Practical verification of the theoretical basis for calculating the maximum reduction in rolling A. Balint (*Met. Constr. Masini*, 1960, (7), 610–617) Rolling in the blooming mill when the ratio l/w is large is accompanied by double convexity and by simple convexity when this ratio is small. When this ratio = 1·25 no convexity forms. Suggestions are made for improving the operation by providing a 2-stand mill with rolls of 1800 mm and 1000 mm dia.

An investigation of the distribution of metal deformation throughout the cross-section of a piece rolled in a beam breakdown pass P. I. Polukhin and V. T. Zhadan (**Obrabotka Stali i Splanov, Sbornik*, 36, *Metallurgizdat*, 1957, pp.228–245) Studies on beams with screws inserted before rolling are reported. Effects of tongue angularity, draught, and spread on deformation pattern were examined. After rolling, thread pitch of the deformed screws was observed and the modes of deformation established.

An investigation of the deformation of metal in flange passes P. I. Polukhin and V. T. Zhadan (**Obrabotka Stali i Splanov. Sbornik*, 36 *Metallurgizdat*, 1957, pp.196–227) Studies of draught, spread, and pass surface conditions were made. Tongue angularity reduces flange height and increases asymmetrical deformation. 50–70° is recommended for small beams. Increasing draught increases flange height without change in asymmetry. Increase of space for spread has little effect. Specific pressure and power consumption are also considered.

Performance characteristics of a rectifier

powered plate mill C. E. Rettig and J. E. Peebles (*Iron Steel Eng.*, 1960, **37**, Aug., 81–90) Details are given of the performance characteristics of the reversing plate and slabbing mill of the Lukens Steel Co. at Coatesville, Pennsylvania, which is powered by a mercury arc rectifier.

AC torque motors for steel finishing lines L. H. Berkley (*Iron Steel Eng.*, 1960, **37**, Oct., 109–113) The function of these motors as a simple, economical means of coiling light or heavy strip mill is discussed.

Determination, by calculation and experiment of the rolling power and output requirements in the hot rolling of sections A. Geleji (*Arch. Eisenh.*, 1960, **31**, Oct., 571–576) Trials to check the method of calculation developed by the author gave results which agreed within permissible limits.

Roll-force and torque coefficients for hot-strip steel mill B. N. Garudachar and H. A. Peterson (*Trans. ASME J. Basic Eng.*, 1960, **82**, Sept., 683–688) Results are presented of an analytical and computer investigation to determine the numerical coefficients involved in the roll-force and roll-torque equations pertaining to a single stand in a multistand, tandem, steel rolling mill. It is claimed that such information has not appeared in the literature to date. The coefficients for a typical hot mill are compared with those obtained for a typical cold mill. The principles of gauge control are discussed and the theories on flat-strip rolling are briefly reviewed.—S.H.-S.

Rolls for rolling mills R. A. Villanueva (*Ing. e. Indust.*, 1960, **37**, Sept., 143–144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166) [In Spanish] The same as the article previously appearing in *Met. Elect.*,

Application and selection of gear type spindles F. H. Paddon (*Iron Steel Eng.*, 1960, **37**, Sept., 91–100) Factors influencing design and application of gear type spindles in rolling mills since 1950, are reviewed.

Steel bloom piping W. Lückerath, K. Fink, and R. Flossmann (*Iron Steel*, 1960, **33**, Oct., 500–405) Some results obtained during continuous X-ray examination of blooms during rolling at the new blooming and semi-finishing mill at Duisburg-Rohrort are described and discussed.

New Ceco mill rolls bars directly from billet-size ingots (*Iron Steel Eng.*, 1960, **37**, Sept., 211, 213) A description of the Ceco Steel Products Corp.'s new plant at Lemont, Illinois, for the direct rolling of ingots from electric arc furnace steel to bar.

Section mills in Venezuela G. Rolle (*Iron Steel*, 1960, **33**, Oct., 506–511) The four mills being installed at the new steelworks on the Orinoco river are described.

High speed rod rolling E. L. Chamberlain (*Iron Steel Eng.*, 1960, **37**, Aug., 147–150) The layout and operation are described of the No.1 high-speed rod mill installed in 1956 at the Cuyahoga Works, American Steel and Wire Div., United States Steel Corp.

Calculation of the thermal conditions for rolling joints and channel beams V. N. Ershov (*Stal'*, 1960, (12), 1119–1121) The use of Tyagunov's formulae with small correcting factors gives good agreement with the web and flange temperatures observed.

The rolling of twin bulb bar sections, splitting them lengthways in the finishing stand rolls I. M. Ektov, V. M. Zaruev, S. A. Gurov, and I. F. Revenko (*Stal'*, 1960, (12), 1113–1115) The process was found to be satisfactory as lengthwise splitting hot can be done at high speed without additional equipment or costs, and the sections come out almost straight and without twists. Burr formation and wear are considered.

Time saving features for merchant mills J. S. Wysocke (*Iron Steel Eng.*, 1960, **37**, Sept., 118–121) Automatic control devices installed by Wisconsin Steel Div. of International Harvester Co., Chicago, at various stages of the rolling process are described briefly.

Modernization of the 160-in plate mill at Sparrows Point J. C. Schaake and T. Massey jun. (*Iron Steel Eng.*, 1960, **37**, Aug., 112–124) Mechanical and electrical features of the installation are described.

Reconstitution of the light section mill at Round Oak Steel Works Ltd. W. S. Walker, J. F. Whitfield, and G. A. V. Russell (*JISI*, 1961, **198**, June, 126–131) [This issue].

Sandwich rolling H. S. Orr and F. R. Romeo (*Iron Steel Eng.*, 1960, **37**, Oct., 151–157) The technique is outlined, and its application to the manufacture of large, thin gauge sheets of special steels described.

Brinsworth steel strip mill. I, II D. H. Lee, G. O. Kee, and N. Lancaster (*Structural Eng.*, 1960, **38**, Feb., 47–56, 56–59) Aspects of construction are discussed. Part II is devoted to the superstructure steelwork.

A fully-continuous narrow-strip and wire-rod mill L. Wegmann (*Iron Steel Eng.*, 1960, **37**, Aug., 159–164) Details are given of the fully-continuous narrow strip and rod mill installed at the Belval Div. of ARBED in Esch-Luxemburg. The billet reheating furnace and auxiliary equipment, billet rolling programs, and special features of the mill equipment are described.

How to roll thinner tin plate N. H. Polakowski (*Met. Prog.*, 1960, **77**, June, 130–132) The need for fast new mills with smaller work rolls is discussed for the purpose of rolling tinplate down to 0·0034–0·004in.

Improving the production technique for cold rolled alloy sheet V. A. Filonov, M. I. Yudin, N. A. Troshchenkov, and V. S. Movshovich (*Stal'*, 1960, (12), 1116–1118) Changes whereby one annealing and one pickling stage were eliminated for 1292A, 25Kh9SA, and 30Kh9SA sheets and for the Mn steel 0·5 mm thick, the intermediate anneal and one rolling cycle as well. The reject rate was also cut to one-third.

Republic research program studies staining of cold rolled steel (*Iron Steel Eng.*, 1960, **37**, Sept., 214, 216) A test is described by which oil stains can be produced on cold rolled steel in a week which would normally take from 2–12 months to develop on steel sheet stored in the field. The results of the tests are being used to predict safe storage times for a steel coated with any given oil.

The application of the mercury arc rectifier to large reversing mill drives M. B. Antrim (*Iron Steel Eng.*, 1960, **37**, Aug., 71–80) A detailed analysis of the comparative costs of the mercury-arc rectifier and the flywheel motor-generator set is given, and shows the former to be the better investment. The study was carried out by Lukens Steel Co., Coatesville, Pennsylvania, and the layout of the equipment installed is described.

Cold plate bending machine (*Metalw. Prod.*, 1960, **104**, June 8, 67) A 3-roll Wagner cold plate bending machine at the Erith works of the General Electric Co. Ltd, for pre-bending and bending steel plate up to 4½in thick is described and illustrated.—S.H.-S.

Electrical maintenance program at the Geneva plant H. A. Huish (*Iron Steel Eng.*, 1960, **37**, Sept., 129–134) The planned reconditioning and spares program for major electrical drive equipment at the Geneva Works of US Steel Corp. is described, with particular reference to the slabbing, plate, and hot-strip mills.

Maintenance in the steel plant: maintenance of rolling mill cranes J. Hertza (*Iron Steel Eng.*, 1960, **37**, Sept., 142–143) The system operated at the Ford Motor Co. works, Dearborn, Michigan, is described.

Application of individual drive motors to live mill tables A. Jakimovich (*Iron Steel Eng.*, 1960, **37**, Oct., 158–166) Advantages of individually driven table rolls are discussed, applications and ratings of table rolls in various plants are listed, and factors influencing design and selection are considered.

Modernizing old equipment J. Dobay (*Iron Steel Eng.*, 1960, **37**, Sept., 121–123) Problems encountered in the modernization of mill table equipment by the Youngstown Sheet and Tube Co., Chicago, are described.

MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

Transportation system R. H. Mody and H. P. Bodhanwalla (*Tisco*, 1960, **7**, July, 214–233) A descriptive historical account of the Tisco plant from its inception in 1907 covering the development of its transportation system to the present day, showing plant layouts in 1910 and 1921 and details of material handled, rolling stock, and permanent way equipment.

Maintenance in the steel plant—maintenance of hot metal cranes R. H. Emmert (*Iron Steel Eng.*, 1960, **37**, Sept., 141–142) Procedure at OH plant of the Ford Motor Co., Dearborn, Michigan is described.

'Traveloader' handles heavy beams at Lackenby (*Iron Coal Trades Rev.*, 1960, **180**, June 17, 1372) Side operating transporter lifts and carries 15 t of 54 ft long beams. It operates in the mill, on sidings for loading, and in stores. Savings in time space and cranes are claimed at Dorman Long Ltd.

The telfer line as a means of transport in industry. The particular case of wood charcoal transport for the iron and steel industry H. Freire (*Bol. ABM*, 1960, **16**, Oct., 779–798; also *Eng. Min. e. Met.*, 1960, **32**, Nov., 291–294) The author describes the telfer system installed by the Companhia Siderurgica Belgo-Miniera for the transport of charcoal to the Monlevade works; it runs 52 km and is one of the largest in the world. An economic study of the method, in comparison with road transportation, is made, and it is shown to have a great economic advantage in this particular case. There is a good possibility that this advantage may apply in other aprts of the national industry.—P.S.

Graphite lubricant reduces flange wear on crane wheels (*Iron Steel Eng.*, 1960, **37**, Oct., 182) The development and application by Ringsdorff Carbon Corp., McKeesport, Pennsylvania, of a new process of dry lubrication for flange wheels of travelling cranes are described.

Mechanization and automation of the transport and loading and unloading operations in metallurgical works K. P. Kostenetskii (*Stal'*, 1960, (11), 1053–1054) A report of a conference convened by Gipromez.

Preventing crane collisions electronically R. J. Meredith (*JIE Eng.*, 1960, **6**, June, 366–367) An acoustic radar system for prevention of factory crane collision is described and its operation and advantages discussed.—S.H.-S.

Reclamation of industrial waste water E. H. Peirce and R. D. Hancock (*Iron Steel Eng.*, 1960, **37**, Aug., 125–130) An account of the conservation and reclamation measures taken at the Geneva Works of the Columbia-Geneva Steel Division of US Steel Corp.

Gas mixing stations can cut fuel costs R. E. Blackwell and N. P. Jacoby (*Iron Steel Eng.*, 1960, **37**, Sept., 200–202, 205) Applications and design of gas mixing stations are reviewed, and examples of installations and control systems are described.

Electronics improve plant operating efficiency (*Blast Furn. Steel Plant*, 1960, **48**, July, 694–695, 719) Experience of the Timken Roller Bearing Co., Ohio, in the use of closed circuit television and intercommunication systems is described with a note on maintenance.

A differential pressure instrument for high temperature service S. A. Hluchan (*Nucl. Eng. Sci. Conference*, 1959, April, 6–9; *Preprint* V–60, pp.19) An instrument for measuring flow and liquid level of process fluid at temp. up to 1500°F and pressures to 500 psi (both conditions not imposed simultaneously) has been developed. It consists of a differential pressure transmitter connected by means of long capillary lines to high and low pressure diaphragm seal units contacting fluid filling with NaK. An unbounded strain gauge force transducer in the transmitter provides a dc electrical output.—C.F.C.

Water supply P. H. Tata and N. J. Dastur (*Tisco*, 1960, **7**, July, 199–213) A survey describing the sources of water supply at Jamshedpur, the arrangements prior to the TMP in 1956, the additional facilities and equipment and their distribution and operation with flow-sheet and illustrations.—S.H.-S.

WELDING AND FLAME-CUTTING

Welding and cutting A. Matting (*VDIZ*, 1960, **102**, Aug. 21, 1158–1160) A review of recent advances in technology in these fields, as indicated in the literature (93 refs).

Roll spot welding of the telescopic joints of tubes of 1Kh18N9T steel Yu. V. Rybakov (*Svaroch. Proizv.*, 1960, (7), 21–24) Telescopic

joints with tight adjustments are most commonly used and the tubes must be strictly checked for dia. and wall thickness for eventual correction. Best results are obtained with a slow rate of welding and long intermittent pauses between the current impulses.

Autogenous arc welding of high-tensile steels, using carbon dioxide blanketing round the electrode materials. Autogenous welding wire materials—60 kg/mm² high tensile steels and CO_2–O_2 autogenous welding T. Okada (*Denki-Seiko*, 1959, **30**, (4), 330–335) 60 kg/mm² high-tensile steels were CO_2–O_2 arc welded, using the following wire electrodes: two kinds of Mn–Si–Cu–Ni, and one each of Mn–Si–Cu–Ni–Cr, Mn–Si–Mi, and Mn–Si–Ni–Cr–Mo–V. Mechanical tests were carried out to ascertain which gave the best results. Mn–Si–Mo 'D' steel rods were preferred: they were excellent to work with, the welded section was not only 10% stronger, but gave a high-cold-impact test figure. Chemical compositions of the high tensile steels and the wires, welding currents and conditions obtaining generally, and results of mechanical tests are given. Standard test pieces with dimensions are shown.

Progress in welding automation (*Ing. e. Indust.*, 1960, **37**, Aug., 132–136, 154) Methods and techniques for submerged arc and slag welding are described; these automatic techniques permit radical variations in the manufacture of large and complex parts.—P.S.

The welding of highly alloyed steels with special reference to shielded arc welding H. Muller (*Metalen*, 1960, **15**, Nov. 30, 382–385) After comparing the arc welding process with other methods of electric and autogenous welding, the author examines the chemical composition, the mechanical properties, and the suitability of ferritic, martensitic, and austenitic steels for use as electrode materials. Besides reference to the chemical composition, attention is also given to the influence of special alloying elements such as Nb and Ti. A number of practical examples is dealt with such as the welding of work-pieces intended for chemical plants, boilers, and gas turbines and also to combinations of welding methods for particular purposes. To conclude, the author touches upon the building up of welds.

Line forms structural members at joist-per-minute rate C. F. Kaunitz and C. H. Guenther (*Iron Age*, 1960, **186**, Sept. 22, 97–99) A new approach to making structural steel joists, centring on a revolutionary welding line, whereby it is possible to produce to order rather than for stock, is illustrated and described, with promises of reductions in handling and storage costs.—S.H.-S.

Automatic building up of rolls V. G. Malinovskii, A. A. Ponomarenko, Z. I. Ber, P. F. Lavrik, and E. L. Slobodchikov (*Svaroch. Proizv.*, 1960, (7), 24–26) Building up with powder wire PP3Kh2V8, with alloy steel wire EI 701 or under ceramic flux of type ZhS–450 increases the strength of the rolls by a small factor. Ceramic flux reduces material consumption by a factor of 4·5 as compared with the consumption with powder electrode wire, also the yield of the operation with ceramic flux is much larger than with powder wire the operation itself is simpler and is strongly recommended.

Induction welding of pressure piping S. L. Gertsman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res. Special Proj. Repts.*, 1960, Jan. 15, 19–20) The internal contour can be made convex, flat, or concave by the method used. Mild and Cr–Mo alloy steels were used and stainless steel can be joined in this way as well. **Weldability of high-strength ship steels** (20–21) Avoidance of cracking has been attained to some extent. **Hydrogen-diffusion effects and heat-affected zone cracking** (21–22) The cruciform and controlled thermal severity tests have been compared. Factors making the former the more exacting are noted. **Prediction of heat-affected zone cracking** (22–23) A new formula is advanced and discussed. **Effect of arc strikes** (23) A zone of great hardness may be produced by accidental contact with the electrode. Impact tests indicate increased possibility of brittle failure which is prevented by welding over the strike area.

The strength of the welding joints of carbon- and alloy steels under simultaneous hot-rolling E. I. Astrov (*Svaroch. Proizv.*, 1960, (8), 4–6) A quantitative relation between the strength of these steel welding joints and the temp. of heating has been experimentally established and a degree of deformation with simultaneous hot-rolling may be made use of in production, on an industrial scale, of multi-layer metallic materials.

The welding of carbon steels in agricultural reaping machines. V V. Ilia (*Met. Constr. Masini*, 1960, (7), 648–654) The weldability of carbon steels with up to 0·5%C is satisfactory (for the thicknesses investigated) if the operation is carried out with coated basic electrodes of the EL 50 type and if the welding schedule recommended is followed correctly. No cracks appear and the heat-affected zone is sufficiently plastic. The electrodes must be calcined before use. For welding steels with a carbon content below 0·25%, electrodes type EL 44 should be used. Welding in layers for steels with a carbon content between 0·3 and 0·5% increases the mechanical properties of the welding joints by refining the structure and improving the plasticity of the heat affected zones. Thermal treatment should be carried out where necessary.

Welders tackle huge bridge job (*Iron Age*, 1960, **186**, Sept. 1, 67) Welding the caisson cutting edges for two huge tower piers for the Verrazano-Narrows Bridge, with structures made of Mn–V steel plate, each unit made up of 28 sub-assemblies, varying in lengths, widths, and heights, are described with brief details of the methods of layout and operations. Total welded length is about 65 000 ft.

Electro-slag welding of 100 mm thick medium-alloy steel forgings G. V. Nazarov (*Svaroch. Proizv.*, 1960, (8), 24–26) The technology of this welding process is explained. The mechanical properties of the joint after heat treatment demonstrate the uniformity with the base metal, and the stable fracture indices show its resistance to brittle fracture.

Pretreatment makes welding galvanized parts easy (*Products Fin.*, 1960, **24**, Feb., 50) A process in use at Westinghouse lighting division in Cleveland, Ohio, which masks weld areas with a solution of $K_2Cr_2O_7$ for 2 min prior to galvanizing is very briefly described.

Welding and strengthening the frame of a forging-stamping press I. A. Kesel'man (*Svaroch. Proizv.*, 1960, (7), 33–34) A welding schedule is given for the operation which is carried out with a few layers in reverse cascade sequences of 120 mm lengths.

Arc welding of high-strength steels for aircraft and missile structures J. T. Niemann, R. P. Sopher, and P. J. Rieppel (*DMIC Mem.* 27; *PB* 161177, 1959, Aug., pp.43) Information collected by the Defence Metals Information Center on the arc welding of a number of hot-work die steels and martensitic and precipitation-hardening stainless steels is presented.

The metal-arc welding of stainless steels. Part IV. Welding stainless steel for high duty service M. C. T. Bystram (*Welder*, 1960, **29**, April–June, 40–44) In this concluding article the use of stainless steel in steam and high temp. equipment and in piping and vessels for the petroleum and petro-chemical industries and in plant for the chemical synthesis of gases is discussed in relation to the welding of thick stainless steels, some materials in the light of present experience, welding procedures, and the welding of stainless steels for service at high temp. in aggressive atmospheres, and further research is predicted.—S.H.-S.

Prediction in new metal joining processes J. J. Chyle (*Trans. SAE*, 1960, **68**, 143–156) New welding processes are described which are claimed to provide improved weld quality and reduced costs. The article describes the following methods: ultrasonics, high-frequency resistance, foil seam, magnetic force, percussion, friction, and diffusion bonding. Adhesive bonding is also discussed.—A.H.M.

Automatic welding of 1Kh18N9T steel under FTsK ceramic flux K. V. Lyubavskii and E. P. L'vova (*Svaroch. Proizv.*, 1960, (7), 1–5) The control of the composition of the weld metal can be carried out effectively by using FTsK-type flux. Approximate calculations (based on the structural diagram) show that for welding this steel with an electrode wire, two alternative fluxes are sufficient to obtain under all conditions a two-phase structure with a ferrite content not exceeding the limits of this structure in the components of the base metal. By alloying in the pool, with Ti via the flux, welding joints are obtained resistant to intercrystalline corrosion after heat-treatment. In automatic welding this flux gives excellent results.

Electrodes for rapid welding E. A. Ivleva and A. M. Gofner (*Svaroch. Proizv.*, 1960, (7), 29–30) Electrodes NII–200, specifications for which are given, increase the yield of the operation as compared with electrodes of type TsM–7 by a factor of 1·5, at the same time facilitating the operation. These new electrodes satisfy the GOST standards 2523–51. For their manufacture the powder made by the Sulinsk Works, Rostov, is recommended.

Electrodes for building up hot forgings I. A. Peremilovskii and R. A. Kablukova (*Svaroch. Proizv.*, 1960, (7), 27–28) The composition is given of a few electrodes for building up hot drop-forgings which produce a satisfactory quality of the deposited metal and increase the mechanical strength of the forgings by a factor of 3 as compared with forgings of 5KhNS steel.

The effect of the non-uniformity of pearlitic steels in the zone of fusion on their properties L. S. Livshits and S. I. Panich (*Svaroch. Proizv.*, 1960, (7), 13–15) The structural non-uniformity which results in many cases in the zone of fusion, manifests itself in the formation of carburized and decarburized zones, unfavourably affecting mechanical properties by reducing tensile strength in view of the stress concentrations in this zone. This necessitates a special hardening of these joints prone to develop structural non-uniformity, because it reduces fatigue strength at high temp. The most damaging effect is that of the decarburized zones.

Weld flaw evaluation S. T. Carpenter and R. F. Linsenmeyer (*SSC*–105, *PB* 161322, 1958, July 29, pp.117) A detailed final report on a series of investigations to determine a basis for the evaluation of the ability of weld flaws to initiate brittle fracture. The report deals with brittle fracture mechanics based on the Griffith theory and on Irwin's strain-energy release rate adaptations, static tests on flawed butt welds, static and dynamic tests on small butt weld flaws with and without residual stress, and static tests on weld flaws in a controlled field of high residual stress (14 refs).

Investigation of the softening zone appearing in the welding of steel S. S. D'yachenko, S. I. German, and Ya. S. Pavlyak (*Metalloved. Term Obra. Met.*, 1960, (7), 24–26) The softened zone is characterized by coarser grain, non-uniform distribution of structural component parts, a deeper pearlite structure, increase in the lattice period of the α-phase as compared with the matrix in the heat-affected zone. The softened strip is the portion of metal subjected in welding to heating up into the intercrystalline range (A_1–A_3).

Evaluation of weld-joint flaws as initiating points of brittle fracture R. P. Sopher, A. L. Lowe jun., and P. J. Rieppel (*SSC*–107; *PB* 161323, 1958, Aug., pp.51) The initiation of brittle fracture from flaws <4 in long is examined, the effect of residual and reaction stresses on the applied stress required to initiate brittle fractures from various types of flaws being considered.

Assessing the resistance of the weld metal to hot cracks V. S. Gavrilyuk (*Svaroch. Proizv.*, 1960, (8), 10–12) Tests should be carried out on a rigid beam with welds on both sides. The effect of the crystallization scheme should also be taken into consideration in the quantitative assessment of the tendency to hot cracking. Specimens of different types of joints should be examined. The replacement of the feldspar on the electrodes by granite does not alter the tendency to hot cracks, nor is it desirable to replace the blast-furnace Fe–Mn of the electrodes.

Bonding of various metals and alloys by isostatic pressing at elevated temperatures J. Fugardi and J. L. Zambrow (*Nucl. Eng. Sci.*

Conference, 1959, April 6–9, *Preprint V*-104, pp.13) A Kanthal furnace inside the pressure vessel enabled temp. to be raised to 1200°C. At this temp., 12000 psi for 20 min was more than enough for good bonding of 347 stainless steel.

Machine type URKhS-4 for oxygen-flux cutting of stainless steels O. Sh. Spektor and B. I. Folomkin (*Svaroch. Proizv.*, 1960, (8), 33–35) The flux is fed to the cutting edge from the outside and this makes it possible to simplify construction and to use normal cutting tools. The cutting rates which can be attained on this machine exceed by a factor of 1·8 to 2·3 those attainable on the previous model by increasing the oxygen supply, while the consumption of flux has been reduced by a factor of 2–4 in comparison with machine type 3.

MACHINING AND MACHINABILITY

Mechanics of orthogonal machining W. B. Palmer and P. L. B. Oxley (*Proc. Inst. Mech. Eng.*, 1959, **173,** (24), 623–654) Slow orthogonal cutting of mild steel was observed by a new technique. A new formulation taking work-hardening into account is presented. It appears to be consistent with plasticity theory in this form.

Surface damage in grinding of steel R. L. Kamm (*Trans. Austral. Inst. Met.*, 1954 and 1955, **7–8,** 111–119) A discussion of abrasives and the processes of grinding and abrasion, with frictional coefficients for chip materials, is followed by a description of cracking, residual stress, grinding burn, and soft and hard skin defects and methods of avoiding these are indicated. Soft steel surfaces are treated separately (32 refs).

Finding the proper rate of feed with respect to the strength of the broaching tool D. K. Margulis (*Vestnik Mashin.*, 1960, (9), 57–62) Contrary to the general idea that with an increase by a small factor in the rate of feed, keeping constant the rate of broaching, the service life of the tool increases by a factor of 2·5–3, investigations at the Chelyabinsk Laboratory for Metal Cutting have shown that in maintaining constant the cutting and structural parameters of the broaches, their service life decreases with an increase in the rate of feed. A special apparatus for the optical analysis of the cutting teeth is described by means of which these observations were made.

U.S. research in ultra-high-speed machining Lockheed Aircraft Corp. (*Metalw. Prod.*, 1960, **104,** May 18, 889–893) Tests recently carried out in the USA, using high explosive as the power source at cutting speed up to 360000 surface ft per min (with a mean between 15000 and 250000) and covering Ti, Al, stainless steel, and alloy steels are briefly described and equipment is illustrated. **2** (May 25, 934–939) The results of recent American tests in ultra-high-speed machining are described and are claimed to reverse the relationship existing in conventional practice, giving decreased tool wear with increased speed and to have increased metal removal rates by 24000%.

Sheet metal data sheet. 10. Manipulation of angle iron J. W. Langton (*Sheet Metal Ind.*, 1960, **37,** Oct., 769–771) Qualitative and semi-quantitative data are given on cutting, shearing, notching, and rolling to curved shapes.

Work handling on metal-cutting machine tools H. Gensert (*VDIZ*, 1960, **102,** Sept. 1, 1202) Abstracted from *VDI-Berichte*, 1959, **40,** 23–26, showing how non-productive machining times can be greatly reduced by correct feeding of the workpiece.

Milling of high-strength steels in the hardness range of 330 to 560 Brinell C. T. Olofson (*DMIC Mem.* 30, *PB* 161180, 1959, Aug., pp.36) Information is given on the face, end, and side milling, and slotting of steels at up to 560 Brinell. Tool cutter compositions and designs are reviewed (30 refs).

Tungsten-carbide and diamond tools, sintered materials (*Wire*, 1960, April, 48) A note of some of the exhibits at the 6th European Machine-Tool Exhibition, Paris, 1959.

Drilling high-strength steels treated to 330 to 560 Brinell hardness A. F. Gerds, C. T. Olofson, and F. W. Boulger (*DMIC Mem.* 31, *PB* 161181, 1959, Aug., pp.14) The necessity for adequate power and rigid setup is emphasized, and the effects of drill composition and geometry are examined.

Accurate measurements on machine tools by using optical reading instruments and precision scales W. Moser (*Microtecnic*, 1960, **14,** April, 39–44) Principles used, methods of setting, and an account of ISOMA development work on optical reading devices are outlined, with examples.

Finish turning A. J. Pekelharing (*Microtecnic*, 1960, **14,** April, 61–69) A description of research carried out by the Technological University, Delft, on wear, minimum surface roughness obtainable with new tools, and methods of maintaining the condition of the tool, and the possibility of establishing a fine-machineability index for materials.

A yield criterion applied to the shear-angle relationship B. N. Colding (*Microtecnic*, 1960, **14,** April, 47–60) A shear-angle relationship is proposed which takes into account the anisotropic properties of the work material and the influence of the feed, and based on a simplified form of Hill's plasticity condition for anisotropic materials. Shear stress along the shear plane is found to be independent of rake angle and cutting speed, but varies inversely as the logarithm of the feed (16 refs).

Electron beam methods move into production A. Lesnewich (*Steel*, 1960, **147.** Sept. 12, 124–127) A brief description of the scope in the growing market for the electron beam metal-working, covering processes, types of equipment, metals to weld, electron beam melting for refining reactive and refractory types of metals, and for special work in machining that can be done in no other way.—S.H.-S.

Tooling problem solved by graphitic die steel J. Risher (*Steel*, 1960, **147,** Sept. 12, 145) 'Graph-Mo', an oil hardening graphitic tool steel produced by Timken Roller Bearing Co., Canton, Ohio, with claims for high abrasion and high wear resistance, is briefly presented.

Chip remover accents safety G. D. Gibbons and J. A. Elder (*Iron Age*, 1960, **186,** Sept. 22, 102–103) A brief description, with comparative photographs, of a vacuum steel chip remover system in operation, collecting waste directly from machined surfaces at Convair, Fort Worth, Texas, with figures of economies effected in operation, production, and man-hours, and with details of increased safety to machine operators.—S.H.-S.

Advantages obtained by 'pre-honing' the cutting edges of tools H. J. Siekmann (*Machinery*, 1960, **97,** Aug. 3, 283–286) Increased and more uniform life of cemented carbide or oxide tools is obtained by hand honing. The notch sensitivity of hard materials is intensified by the high stress concentration at a cutting edge. Electron microscopy confirms that honing removes the damage at the edge produced by grinding, and makes a sound cutting edge of improved geometrical form.—J.W.J.

Work hardening and surface finish in the treatment of stainless steels N. P. Golubov (*Stanki Instr.*, 1960, (8), 31–32) Investigations of the 1Kh18N9T and 40 Kh steels have shown that a change in the cutting depth from 0·5 to 3 mm does not affect the surface finish, but the finish deteriorates with an increase in the rate of feed. The rate of feed and the depth of cutting affect the degree and the depth of the hardened layer.

The production of the Simca Aronde P. A. Sidders (*Machinery*, 1960, **97,** July 13, 80–92) Detail of machining operations for the steering and follower links by the Hüller in-line transfer machine are given, operations at each working stage and dimensions after completing are shown, and gauges are described.—J.W.J.

Ceramic or carbide tools—which? D. R. Kibbey and H. D. Moore (*Metalw. Prod.*, 1960, **104,** Aug. 17, 62–63) A brief comparative report on the use of ceramic tools for turning speeds above 800–900 surface ft per min, and carbides for speeds under that is based on the findings of a research project carried out at the engineering experimental station of Ohio University. Numerous qualifying factors are admitted.—S.H.-S.

CLEANING AND PICKLING

Surface cleaning and surface treatment Sachs (*Wire*, 1960, April, 35–39) A description of automatic equipment shown at the 6th European Machine-Tool Exhibition, Paris, 1959.

Can power brushing help you in finishing? (*Products Fin.*, 1960, **24,** April, 36–45) A detailed descriptive review, with photographs, tables, and graphs by the Osborn Mfg. Co. of Cleveland, Ohio, showing how to choose and use brushes and the machines that drive them. A wide variety of uses is presented.—S.H.-S.

What precision barrel finishing can do J. J. Forrester jun. (*Products Fin.*, 1960, **24,** March, 54–56) A precision process, replacing the inexact tumbling method of 50 years ago, is described in which a special electric furnace product provides the crude material for a medium specially designed for burnishing operations and the development of high colour. Better finishes, closer tolerances, and lower cost are claimed for a wide variety of products.

How Pesco Products improved deburring (*Products Fin.*, 1960, **24,** March, 64–68) A ten-compartment barrel finishing machine in operation at the Borg-Warner Corporation's Pesco plant is claimed to substitute batch-finishing in loads of up to 5000 and 10000 pieces for hand finishing, with closer and more uniform work standards and for greater speed and economy of operation.—S.H.-S.

Abrasive slurry deburrs at high speed (*Metalw. Prod.*, 1960, **104,** June 8, 83, 84) The Rotofinish Roto-Matic spindle polishing machine, using a spinning tub of abrasive slurry, and claiming finishes consistently as good as 10 micro-in is described with operational detail.—S.H.-S.

Precise barrel finishing R. F. Enyedy (*Met. Fin.*, 1960, **58,** July, 85–90) Barrel finishing methods, self-tumbling to deburr and polish and for other purposes, and barrel finishing with media are discussed, with a detailed description of the different operations and their objectives. (Aug., 54–59) Design of barrels and the form and composition of media used for various deburring processes are described.

The kinetics of scale removal from strip of stainless 1Kh18N9T steel in nitric acid A. I. Matantsev (*Zhurn. Prikl. Khim.*, 1960, **33,** (3), 674–685) Experiments on the removal of scale in HNO_3 at from 0·4 to 40% concentration at temp. from 18 to 80° have shown that the process of loosening the scale is conditioned by the kinetics of the chemical and electrochemical processes. A consideration of the temp. coefficients of these reactions shows that both the diffusion and the electrochemical reactions are limited by the conditions of the operation, but it has become obvious that it is possible to control etching and direct it as desired. **The kinetics of the removal of scale by nitric acid solutions** ((6), 1285–1292) Experiments for studying the kinetics of loosening of the scale by etching specimens of type 1Kh18N9T stainless steel strip on a 6·5%HNO_3 solution with additions of between 0·5 and 20%NaCl at 18, 50, and 70° have established that the electrochemical explanation of the pressure observed in these solutions is simplified if the composition and the properties of the steel and the scale are taken into consideration, also the specific surface activity of the NaCl and its participation in a number of electro-chemical processes. In effect the curves of potential/time and those of the cathode and anode polarizations show that the loosening of the scale is limited by the reactions at the electrodes.

Service and maintenance for continuous hot and cold pickle and annealing lines A. A. De Blander (*Iron Steel Eng.*, 1960, **37,** Sept., 148–149) Maintenance of various parts of the plant is described briefly.

The advantages of nitric acid pickling in tinning H. Anders (*Met.-Reinigung Vorbeh.*, 1960, **9,** Aug., 136–137) Given careful control of conditions, HNO_3 pickling gives satisfactory 'wettability' in subsequent hot-dip tinning.

Continuous pickling of silicon-steel strip (*Sheet Metal Ind.*, 1960, **37,** Oct., 766–768) A description is given of the continuous pickling lines of Brierly Hill works of RTB, with illustrations. The lines include pickle tanks, covers, wash tanks, and pre-scrubber tanks. Details of method of heating and fume extraction are given.—A.H.M.

Purification of hydrochloric acid solutions from iron by extraction P. V. Dybina (*Zhurn. Prikl. Khim.*, 1960, **33**, (10), 2184–2189) Extraction of iron from hydrochloric acid solutions by butyl acetate for iron concentrations of 25 g/l ensure practically complete purification and the degree of iron-extraction reaches 99·97%. With increasing concentrations of hydrochloric acid, the degree of iron extraction increases and attains a maximum in 9–10 molar solutions. Optimum extraction is obtained with iron concentrations of between 10 and 25 g/l. With greater iron concentrations the degree of extraction diminishes.

PROTECTIVE COATINGS

Science for electroplaters: 58. Adhesion L. Serota (*Met. Fin.*, 1960, **58**, July, 102–103, 105) The forces involved in adhesion are discussed, together with cohesion and diffusion or alloy formation, and the opinions of a number of named authorities are presented.—S.H.-S.

Finishing pointers. Plating bath limits J. B. Mohler (*Met. Fin.*, 1960, **58**, July, 91, 99) The importance of plating bath limits, those based on actual experience and 'tentative', is briefly discussed, and the need to start with a standard bath and defined limits is suggested.

Relation between coating thickness and protection L. I. Kadaner and A. Kh. Masik (*Electropl. Met. Fin.*, 1960, **13**, May, 167–168) Laboratory experiments show that when thickness of electrodeposited Zn on Fe increases, corrosion rates decrease at first due to reduced porosity, but as thickness increases, this effect is offset by increased corrosion rates as the structure is coarser and less homogeneous. Tinned samples gave somewhat similar results.—J.W.J.

Automatic load-unload on plating machine Gillette Industries Ltd (*Metalw. Prod.*, 1960, **104**, May 4, 822–823) The Efco–Udylite Junior automatic handling 7 200 parts per hour is illustrated and described in brief.—S.H.-S.

Simplified mechanism for automatic plater (*Metalw. Prod.*, 1960, **104**, May 25, 952) An installation is described in detail, and illustrated, of a new type of automatic plating machine of simplified construction, which is claimed to have doubled the plating capacity at AEI Hotpoint Ltd. Electronic times on master control panel sequences plater operation, permitting variation of process timing where necessary. Equipment and course of operation are shown.—S.H.-S.

Titanium racks and hooks for plating and anodizing (*Products Fin.*, 1960, **24**, June, 76–78) Two methods, one using titanium, the other using aluminium, for racks in nickel plating are described and compared, with advantages being claimed for titanium.

Adherence of thick chromium deposits as affected by surface preparation J. G. Poor, H. Chessin, and C. L. Alderuccio (*Plating*, 1960, **47**, July, 811–813) Photomicrographs show that honing, usually considered a relatively mild machining operation, can cause extensive damage to metal surfaces. Machining, grinding, even polishing, can also cause sufficient damage to metal surfaces to affect the bond strength of electrodeposits on these surfaces. Where electrodeposits are liable to severe stresses in service, it is especially important to remove these weakened surfaces before plating.

Structure of electrodeposited chromium M. Matsunaga (*Sci. Pap. Inst. Phys. Chem. Res. Jap.*, 1960, **54**, June, 177–183) Crystal orientation and the degree of specular gloss of electrodeposited Cr have been studied at current densities of 10–100 A/dm² and 20–70°C by using three types of chromic acid baths. The brightest deposits are characterized by (111) preferred oxidation as shown by Yoshida, Hume-Rothery, and Wyllie. Diagrams show the effect of temp. and cd on the degree of specular gloss and crystal orientation of the deposits. In addition to (111), (110), and modified (111) are formed at high temp.—S.H.-S.

Industrial nickel plating (*International Nickel Co. Inc., pamphlet*, 1959, pp.17) Uses, and the effects of corrosive agents are given.

Quality plating with thicker nickel coatings (*International Nickel Co. Inc., pamphlet*, pp.7) With tables of thickness and exposure test results.

Nickel bath with good tolerance for impurities (*Products Fin.*, 1960, **24**, March, 45–47 A process in 16 stages carried out in a Hanson-Van Winkle-Munning automatic plating machine at the works of the New Britain Machine Co. in Connecticut, and called the 'Levelmax', bright nickel bath, is illustrated and described.

Iron-cobalt alloy plating from the pyrophosphate bath V. Sree and T. L. Rama Char (*J. Sci. Indust., Res.* 1960, **19B**, June, 223–224) A letter. Bath composition and preliminary results are given.—S.H.-S.

Zinc coatings on iron and steel A. K. Parker (*Met. Fin. J.*, 1960, **6**, Sept., 345–354, 363) An illustrated review, summarizing applications of zinc coatings in 14 fields: agriculture, aircraft, buildings, bridges, and tunnels, defence, domestic and institutional, electrical and electronic, gas works, industrial plant, marine, railways, road vehicles, ventilation, water-supply, and miscellaneous.—S.H.-S.

Galvanized coatings S. L. Gertsman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res., Special Proj. Rept.*, 1960, Jan. 15, 25–26) Effects of additions of Sn, Cd, Sb, and Cu in presence or absence of Al and Pb were examined. Arrangements for corrosion tests are being made.

Strip galvanizing gains popularity T. F. Olt and K. Oganowski (*Steel*, 1960, **147**, Sept. 26, 124–125) The Armco-Sendzimir galvanizing process pioneered by Armco Steel Corp; of Middletown, Ohio, featuring oxidation and subsequent reduction of steel strip, followed by immersion in molten zinc, originally operated at Butler (Pa.) in 1936, is now presented in modernized form, controlled by adding Al to the zinc bath. Numerous improvements are briefly described and various plants in operation in the US and several overseas countries are cited.—S.H.-S.

A novel system for galvanizing small quantities of parts Blasberg GmbH (*Tecn. Indust.*, 1960, **38**, Sept., 1484) The Kadett galvanizing drum is described, it weighs 6 kg, takes a load of 3 to 4 kg, and is easy to operate.—P.S.

Steel plants add quality control to tinplate production lines Cutler-Hammer Corp. (*Iron Steel Eng.*, 1960, **37**, Oct., 185–186, 188) The AIL data accumulation system for gathering information for quality control while running tinplate coils is described.

Automatic feeding of sheet for slitting, oiling and tinning (*Sheet Metal Ind.*, 1960, **37**, Aug., 593–594, 596) The well-illustrated article gives details of equipment developed by the Tennessee Coal and Iron Division of the United States Steel Corp., for mechanically feeding tin and black plate to slitters, oiling machines, sheet counters, and tin pots.—A.H.M.

Oxidation characteristics of tin-plating electrolytes J. A. McCarthy (*Plating*, 1960, **47**, July, 805–810) An investigation is described in which various tin-plating electrolytes were subjected to a controlled stream of pure O_2 and the degrees of oxidation measured and compared. Data indicate a wide difference in the tendency of electrolytes to oxidize and that oxidation of stannous to stannic tin could be a serious problem, with some electrolytes under certain operation conditions. The low-sulphate phenolsulphonic acid electrolyte showed best oxidation. Other tin-plating electrolytes studied were chloride–fluoride, fluoroborate, high-sulphate phenolsulphonic acid, pyrophosphate, sulphamic acid, and sulphuric acid. Results are briefly summarized.—S.H.-S.

The tinplate industry, with special reference to the cold reduction plants of Trostre and Velindre J. S. Gazard (*South Wales Inst. Eng.*, 1959, pp.19, preprint) A review of plant and process with a brief historical introduction and statistics of alternative materials and of canned food production.

Bronze plating solves finishing problems F. A. Lowenheim (*Met. Prog.*, 1960, **77**, June, 126–129) A description of a commercially-available process for plating Cu–Sn alloys; it has good throwing power, and is easily controlled and plates rapidly.

Protection of steel parts by vacuum deposition of cadmium Catalyst Research Corp. (*Machinery*, 1960, **97**, 1411–1413) The process is described. H_2 and Cl_2 embrittlement must be absent, coatings must not flake, peel, or blister, salt spray must be withstood for 192 h, opacity must equal and coverage must exceed that of electroplated Cd.—C.V.

Copper plating of steel in an ammoniacal electrolyte containing univalent copper ions V. D. Kamkin and M. L. Pertsovskii (*Zhurn. Prikl. Khim.*, 1960, **33**, (5), 1215–1216) An electrolyte without cyanide has been evolved for copper plating, based on a cuprous amine and characterized by its great chemical purity and high rate of electrolytic deposition of copper.

The field of metal spraying in industry widens (*Tecn. Indust.*, 1960, **38**, Sept., 1519–1521) A general discussion of metal spraying and examples of its applications are provided.

Chromium electroplates for corrosion protection of stressed AISI 410 in high temperature, high purity water H. Suss (*KAPL–M–HOS–8*, 1959, Sept., pp.29; from *Nucl. Sci. Abs.*, 1959, **13**, Dec. 31, 2997) The use of Cr plating has given anomalous results. The coating either offered protection under conditions which produced failure in unplated material or caused accelerated failures under conditions in which unplated material did not fail. Factors which may have contributed to these results are discussed. Cr deposits are not recommended for corrosion protection of AISI 410 materials susceptible to stress corrosion and/or intergranular attack.

Chromium electroplates for corrosion protection of stressed AISI 410 steel in high temperature, high purity water H. Suss (*Corrosion*, 1960, **16**, Oct., 497t–502t) The authors show that Cr plating should not be used for the protection of AISI 410 steel against stress-corrosion cracking in high temp. high purity waters. It has also no advantage from the point of view of pitting attack in similar oxygenated waters.—G.F.

A study of the possibility of perfecting the process of Cr-plating. Part II J. Socha and T. Zak (*Prace Inst. Mech.*, 1958, **7**, (22), 41–45) After a study of the influence of SiF_6, SO_4, and Sr-ions on coating capacity it was established that the concentration of 400 g/l of CrO_3 increased the covering power of the Cr baths as compared with the standard H_2SO_4 bath.

Chromium plating solution regeneration by ion exchange with the aim of easing the waste water problem of plating plants H. Wiedmann (*Metalloberfläche,*, 1960, **14**, Nov., 341–345) Based on American and Swiss experience in the regeneration of Cr plating solutions the author studied the efficiency of an ion-exchange process using styrene-divinylbenzene type resins which have a life of about 1 200 cycles. The plant for the treatment and the equipment for measuring the quantity of metal ions present are described. The results obtained are discussed and presented in various graphs.

Black chromium plating (*Prec. Met. Mold.*, 1960, **18**, May, 67) Solvay Process Div. of Allied Chemical Corp. has developed an electro-plating bath for direct plating of black Cr on any conductive material in standard electroplating equipment. The bath is basically CrO_3 and a fluorine-bearing catalyst ion. A table lists the plating conditions for a number of test panels of different base metals.

Practical nickel plating (*International Nickel Co. Inc., pamphlet*, 1959, 2nd ed., pp.55) Processes are reviewed with considerable amounts of tabulated data and description and illustrations of uses.

Science for electroplaters: 57.Nickel L. Serota (*Met. Fin.*, 1960, **58**, May, 63–65) Ion properties and bath compositions are given.

The different kinds of nickel-plating baths (*Galvanotech.*, 1959, **50**, March, 123–127; from *Galvano*, 1960, **29**, Aug., 447) Formulas and operative methods of 14 different nickel-plating baths and their appropriate respective uses are given.

Preliminary treatment for nickel plating (*Galvanotech.*, 1959, **50**, March, 118–125; from *Galvano*, 1960, **29**, Aug., 448) Preliminary processes for the preparation of aluminium and of zinc for nickel plating, and the methods attending their application are described.

Nickel plating in thick and hard coatings H. Benninghoff (*Galvanotech.*, 1959, **50**, March, 127–131; from *Galvano*, 1960, **29**, Aug., 448) The methods requisite for cleaning the surface

after mechanical polishing and degreasing, prior to plating, are briefly indicated.—S.H.-S.

Causes of defects in nickel plating O. A. Stocker, A. Korbelak, and S. A. Carrano (*Galvanotech.*, 1959, **50**, March, 132–138; from *Galvano*, 1960, **29**, Aug., 449) Tables reviewing 11 classes of defects, with possible causes and means of avoiding them, are listed, and are claimed to constitute a real 'Manual of Perfect Nickelling'.—S.H.-S.

Brittleness of brilliant nickel coatings K.-H. Hartung (*Galvanotech.*, 1958, **49**, Feb., 42–44; from *Galvano*, 1960, **29**, Aug., 449–450) A new bending test, superseding the Erichsen bending and folding test, by placing a nickel-plated steel strip in a special apparatus is described, and is claimed to be suitable for other platings as well as nickel.—S.H.-S.

Elimination of impurities in nickel-plating baths (*Galvanotech.*, 1959, **50**, March, 139–143; from *Galvano*, 1960, **29**, Aug., 450) Processes for the elimination of various types of impurities by electrolytic and chemical action are indicated.—S.H.-S.

How to tell good hot dip galvanizing Midwest Job Galvanizers Association (*Steel*, 1960, **146**, June 27, 76–79) A guidebook on the quality of hot dip galvanizing is reviewed. The conditions necessary for good results are explained, and possible defects are described and illustrated.

Zinc plating of steel shell cases H. J. Bache and R. F. C. Robinson (*Met. Fin.*, 1960, **6**, July, 265–272) The operation of an automatic Efco-Udylite plant, return type, is described and illustrated. Effects of aeration on the composition of solutions and choice of materials for anodes are discussed.—J.W.J.

Some American experience in the mechanization of hot-dip galvanizing H. S. Hansen (*Met. Fin.*, 1960, **6**, July, 273–275) Production for hot dip galvanizing is so varied that complete automation is not possible. A mechanized plant developed by the Hot Dip Galvanizers Assoc. is described and illustrated. Quality and working conditions are improved and costs are reduced. Electrical programme timers control operations and coating thickness is maintained.

The influence of aluminium in the iron and in the zinc bath on zinc attack D. Horstmann (*Forsch. Wirts. Nordrhein-Westfalen*, 1958, (620), pp.29) The attack of iron-saturated Zn melts on Al-containing iron, and the inhibiting action of Al in Zn baths on the Zn attack are investigated (30 refs).

General principles of the effects of accompanying elements in the iron on the processes taking place in hot-dip galvanizing D. Horstmann (*Stahl Eisen*, 1960, **80**, Oct. 27, 1531–1540) The author evaluates published information on the attack of zinc on iron during hot-dip galvanizing for deducing general principles of the effects of accompanying elements in the iron on processes taking place in hot-dip galvanizing. He deals with the effects of the following elements: P, Ti, Mo, Ni, Mn, Cr, Si, and Al. The formula derived for the prediction of the corrosibility of the iron containing any of these elements by molten zinc is valid only in the temp. range in which the parabolic time law is applicable; at higher temp. where the linear time law holds, no predictions can be made owing to the complexity of the effects (29 refs).—T.G.

Recent laboratory findings on hot dip galvanized high tensile steel plates H. H. Walkup, H. W. Wotring, and L. R. Abbot jun. (*NNSY C*–380 Rept. 5382; *PB* 146233, 1957, Oct., pp.81; from *US Res. Rep.*, 1960, **34**, July 15, 76) A report on an investigation of military specification MIL–5–16113 B (NAVY) to determine if coating requirements resemble those on commercially galvanized plates, with the addition of data on 11 galvanizing activities, relative tests, and results.—S.H.-S.

Expansion of electrolytic tinning facilities at Pittsburgh Works T. B. Bruce, R. L. Dowell, and P. P. Gottschall (*Iron Steel Eng.*, 1960, **37**, July, 82–92) Development over recent years at the Pittsburgh works of the Columbia-Geneva Steel Div. of US Steel Corp. is outlined, and a detailed description is given of the design and operation of the existing plant.

Modern plant for tinplate manufacture (*Ind. Fin.*, 1960, **12**, Sept., 53–55) Brief details are given of the manufacture of tinplate at Steel Co. of Wales Ltd, particular attention being given to the Velindre Works. The chief items of equipment mentioned are the 5-stand cold reduction mill, the continuous annealing line, and the electrolytic tinning lines.—G.F.

Aluminizing of low carbon steels in liquid baths C. Niewiadomski and A. Zdanowski (*Prace Inst. Mech.*, 1958, **7**, (22), 11–20) On examining such factors as the preparation of the surface destined for Al coating, prevention of oxidation during submersion in the bath, the influence of bath temp., the period of submersion in the bath and the effect of adding other elements to the bath as well as the effect of contamination by the iron, the optimum conditions are established and certain theoretical details of diffusion are considered. In conclusion, the authors consider the mechanical properties of the coatings formed.

The influence of brightening agents on the electrolytic deposition of iron–chromium–nickel alloys M. Machu and M. F. M. El-Ghandour (*Werks. Korros.*, 1960, **11**, Oct., 628–631) The effect of brightening agents in the deposition of an Fe–Cr–Ni is much less than when the single elements are deposited. This is attributed to the inhibiting effect on the adsorption film of the brightening agent of the Cr hydroxide diaphragm formed on the cathode surface. The mechanism of the brightening action is discussed.

The protection of iron and steel by aluminium coatings D. R. Andrews (*Metallurgia*, 1960, **62**, Oct., 152–158) Various processes in use are described and discussed, with special reference to metal spraying, hot-dip aluminizing and calorizing. The structure and properties of each type of coating are indicated (11 refs).

Low pressure spraying Vaughan (*Ind. Fin.*, 1960, **12**, Aug., 34–36) The advantages and disadvantages of spraying compared with other methods of enamel application are discussed. The design of the spray and the control of its application are considered.—G.F.

Automatic spraying plant W. E. Stanton (*Corros. Prev.*, 1960, **7**, Aug., 38–40) An automatic spraying machine will deal with some 20 different components. A control plate with drilled parts is inserted to decide the cycle of operations. Two pistols combine to produce a spray band 8 in wide. They can retract 26 in and rotate vertically through an included angle of 180°. Pneumatic operation also lends itself to manual control.—J.W.J.

Metal spraying progress J. H. Payne (*Corros. Prev.*, 1960, **7**, Aug., 35–37) Costs are reduced by spraying even large sections in the factory instead of on site. A girder 5 ft by 40 ft is mentioned. Paint applied immediately after spraying improves life. Hard-facing materials such as Stellite resist corrosion and wear. The latter is improved by impregnation with colloidal graphite. Rocket venturis are sprayed with Al_2O_3 and ZrO_2 to resist heat and erosion. Copper spraying of walls and floors helps with radio screening.—J.W.J.

Important developments in metal spraying G. A. Curson (*Corros. Prev.*, 1960, **7**, Aug., 41, 45) Experiments over seven years suggest that sprayed alloys of Al with Zn offer better protection against corrosion than the pure metals.

Heat resisting Al–Cr diffusion coatings on low carbon steel obtained by metal spraying S. Gebalski (*Prace Inst. Mech.*, 1958, **6**, (23), 28–45) In an introduction the author discusses briefly modern oxide-ceramo-metallic and metallic heat resisting coatings and he deals with diffusion Cr–Al coatings. He then goes on to original work. The final conclusions are: with a spraying technique applying successive coatings of high Cr steel and Al it is possible to obtain, after diffusion heating, a heat-resisting coating on low-carbon steels; this laminating method gave results superior to those from straight Al diffusion coatings.

Methods for investigating the characteristics of reactive coatings M. Kronstein (*Corrosion*, 1959, **15**, Oct., 508t–512t) The author describes the development of methods which have been applied to the investigation of reaction coatings formed by the application to metal of inorganic chemical surface coatings and by pigmented reactive organic coatings. Such coatings are shown to produce a chemical modification of the substrate; they can be analysed by spectroanalytical methods and their formation can be controlled and modified systematically.—G.F.

Composition of zinc phosphate coatings J. Doss (*PB* 147432, 1957, Oct., pp.21; from *US Govt. Res. Rep.*, 1960, **34**, Aug. 19, 128) Determinations were made for PO_4, Zn, and Fe in zinc phosphate coatings formed in four different solutions after various processing times. The percent of PO_4, Zn, and Fe found in zinc phosphate coatings remains approximately the same regardless of the processing time, the accelerator used, or the operating condition of the phosphating solution. The coatings were found to contain approximately 40·8%PO_4, 12·3%Fe, and 32·3%Zn. The sum of the above percentages was found to be approximately 85·4. The remaining 14·6% of the coating was presumed to be water.—C.F.C.

Comparative investigation of protective organic finishes J. Zawadzki, J. Baczewski, and J. Weber (*Prace Inst. Mech.*, 1958, **6**, (23), 73–86) Coatings of phenol-formaldehyde, epoxide, and furan types were applied over phosphate coatings of 'Fosfatin R', 'Bonder 50' as well as on varnish-based primer containing zinc chromes. They were tested for elasto-adhesion, hardness, abrasion- and impact-resistance as well as resistance to 3%NaCl. The test showed that metal surface pretreatment before painting has a greater effect in improving mechanical and protective properties of phenol-formaldehyde than composition change that the best mechanical properties were obtained with epoxide enamels (with the exception of impact resistance), that coatings applied to phosphated surfaces gave better protective qualities to surfaces coated with primer, that mechanically, Fosfatin R was most suitable as undercoat for stove enamels, and that thickness has a profound effect on the protective properties of paints with an optimum of 20–25 μ.

Plastic linings for tanks and containers (*Corros. Prev.*, 1960, **7**, May, iv–v) The materials most suitable and the criteria governing their choice and use are briefly described, either in the form of sheet or as a coating.

Anticorrosive materials and products P. Badet (*Galvano*, 1960, **29**, March, 137–140) A review of the action of various plastic, wax, and rubber coatings and vat linings with tabulated analyses.—S.H.-S.

Strippable protectives E. S. Lower (*Ind. Fin.*, 1960, **12**, Oct., 46–48) The author reviews the field of protective anti-corrosive coatings which can be used to protect castings and to provide a transparent packaging with sales appeal.—G.F.

The enamelling of ferrous metals P. Tyvaert (*Corros. et Anticorros.*, 1960, **8**, Sept., 319–331) In this article, the author undertakes a general outline, confining himself to fundamental principles and to the technical aspect of industrial processes, often imperfectly understood despite their old-time origins and their more recent applications.—S.H.-S.

Fundamental of glass-to-metal bonding. VIII. Wettability of iron by molten sodium disilicate R. W. Cline, R. M. Fulrath, and J. A. Pask (*California Univ. Minerals Res. Lab.*, 1960, March, *Technical Progress Report*, (8), pp.30; *TID*–5754; from *Nucl. Sci. Abs.*, 1960, **14**, July 31, 1778) The contact angle was measured in apparatus described. On Armco it was 55±2° at 900–1 000°C *in vacuo* with poor adhesion. Dissolution of oxide producing fayalite gave angles of 15–35° with optimum adhesion. Zn foil in the system reduced grain growth of the iron.

Steelmakers market new enamelling sheet (*Steel*, 1960, **146**, June 20, 139–140) The advent of one-coat 'direct on' enamelling sheet is described. In US the Bethlehem Steel Co. has the sheet in production, and three other concerns will be in production soon. The sheet has a low carbon content and a regular cold-rolled surface. It is hoped that the material will replace the two-coat type and some of the plain cold-rolled sheet which is used for enamelling.—D.L.C.P.

Gold for furnace linings: A new approach to vitreous enamelling (*Ind. Fin.*, 1960, **12**, Nov., 35–36) The Californian Metal Enamelling Co. has successfully introduced gold as a lining for its enamelling furnace, the high reflectance of

the gold coating permitting more efficient operation of the furnace. The method of applying the coating is described and its properties are given.—G.F.

Chemical resistance of glass-lined steel (*Corros. Prev.*, 1960, **7**, May, 51–58) A constructional material for chemical plant which combines high chemical resistivity with the required mechanical strength is Pfaudler glass-lined steel. A table gives its resistance ratings against over 30 different chemicals; its physical properties are also described.

Red lead and white lead for protection of iron and steel A. G. Walker (*Corros. Techn.*, 1960, **7**, May, 139–141, 162) Compositions of various types and their selection for the best results are reviewed.

Coating performance in a marine environment evaluated by statistical methods F. E. Cook and A. S. Marthens (*Corrosion*, 1960, **16**, Aug., 411t–414t) The authors describe a simple test used for evaluating the performance of protective paints. The results are analysed statistically.—G.F.

Chemical conversion of metal surfaces for improved corrosion resistance R. F. Ayres (*Met. Prog.*, 1960, **78**, Sept., 101–107) The basic principles of surface conversion reactions are surveyed.

Some techniques in studying rates of deposition and formation of inorganic films on metal surfaces H. R. Thirsk and W. F. K. Wynne-Jones (*Trans. Inst. Met. Fin.*, 1959, **36**, Winter, 198–202; discussion 202) The use of relaxation techniques in electrochemical kinetics is described with reference to anodic electrocrystallization. It is suggested that analogous methods would be applicable to a study of cathodic processes.—A.D.H.

Recent advances in fused plastic coatings for metals D. E. J. Cunningham (*Trans. Inst. Met. Fin.*, 1959, **36**, Winter, 189–196; discussion 196–197) Practice for coating metals with nylon, polythene, synthetic rubber, CAB, shellac, and epoxy resin by powder spraying, powder dipping, and flame spraying is described and applications of the coated products are given.—A.D.H.

Polysulphide-epoxy coatings solve abrasions and corrosion problem on hopper cars (*Products Fin.*, 1960, **24**, Feb., 52) A coating composed of polysulphide liquid polymer and epoxy resin for fertilizer and chemical-carrying railroad steel hopper cars, supplied by Thiokol Chemical Corp. for both internal and external spraying is claimed to have a 5 year service life without need for additional painting.—S.H.-S.

Epoxide resins for corrosion resistant applications G. J. Powell (*Corr. Prev.*, 1960, **7**, March; *Corrosion Engineer*, 1960, **2**, March, (3), ii–vii) The use of 'Epikote' resins with their physical properties tabulated, for corrosion protection, with their marine and exterior plant protection applications and some ancillary materials are reviewed. A discussion follows:—S.H.-S.

Organic protective coatings A. T. S. Rudram (*Chem. Ind.*, 1960, Dec. 31, 1608–1616) A general discussion dealing with coatings as applied to gas making plant and equipment, paints, inhibitors, bitumen, and tar, polymers, rubber, and polyesters as used on iron and non-ferrous metals are reviewed.—C.V.

Production lines keep rolling during modernization programme (*Products Fin.*, 1960, **24**, April, 64–66) Methods employed by the R. C. Mahon paint finishing firm at the Studebaker-Packard plant at South Bend, Ind., in order to avoid loss of production during plant shutdown, by means of segmentizing, proceeding in stages, on the work entailed, is described.

'Direct-on-white' enamels A. H. Symonds (*Met. Fin. J.*, 1960, **6**, Sept., 362–363) A lecture, delivered at an annual series of refresher courses in vitreous enamelling, discussing the relative merits of various acid pickling processes in relation to the one-coat finish, with a summary of suitable types of enamels.

Panel discussion of painters' problems L. L. Diveley, O. Spawn, A. Andreoni, R. Hazuchs, and L. Gilbert (*Products Fin.*, 1960, **24**, June, 50–54, 56) Brief answers are recorded on steel composition effects on phosphate coatings, and removal of cold-working surface conditions, chromic acid washes and wash primers, epoxy and silicon coating effects, colour matching, etc.

CLAD SHEET AND HARD FACING

Plasmajets headed for production roles B. Lohrie (*Steel*, 1960, **147**, 110–112) Plasmajets, working with streams of superheated gases generating some 35000°F for depositing refractory metals and ceramic materials are described. The plasma gun has a water-cooled chamber with an arc in its centre through which an inert gas passes. The arc dissociates the gas molecules into a stream of hot ionized particles with temp. claimed to be high enough to melt or vaporize anything. Numerous applications are suggested and some examples presented.—S.H.-S.

Hard surfacing of blast furnace bells and hoppers R. Fluck and C. W. Dunn (*Iron Steel Eng.*, 1960, **37**, Sept., 183–190) Details are given, illustrated by photographs, of the hard surfacing technique carried out by Bethlehem Steel Co.

Hard chromium plating of piston rods: Preparation and finishing Atlas Plating Works Ltd (*Machinery*, 1960, **97**, Dec. 28, 1466–1467) If a mirror finish is required, a low micro-inch surface is first produced with a fine belt; this is removed and finally polished with a special type of mop.—C.V.

Hard chrome plating cylinder liners Laystall Cromard Ltd (*Met. Ind.*, 1960, **97**, 319–321) A brief description is given, together with layout of a plant used for deposition of hard chrome on the bore of deep drawn steel liners used in internal combustion engines. Automatic units are described and increased productivity claimed.—A.H.M.

Life of high speed steel increased by carbide coating Impregnated Diamond Products Ltd (*Machinery*, 1960, **97**, Aug. 10, 336–338) Wear resistance is increased and toughness retained for high speed steel by coating with 0·0005in of carbide by means of spark machining equipment. Increased tool life up to 400% is reported. Single point tools, reamers, and plain milling cutters are easily treated.

Ceramic coating fills the gap for corrosion-free designs E. A. Sanford (*Iron Age*, 1960, **186**, Sept. 29, 118–119) A new construction material, Nucerite, combining structural strength, resistance to impact damage, and resistance to attack in hot corrosive environments is described, and laboratory and field tests, and many probable uses are briefly discussed.—S.H.-S.

POWDER METALLURGY

Electrolytic production of highly dispersed iron powders N. T. Kudryavtsev and N. I. Mikhailov (*Zhurn. Prikl. Khim.*, 1960, **33**, (6), 1360–1365) The optimum acidity of the solution containing 82 g/l $FeSO_4$, $7H_2O$ (~0·6N) corresponds to pH 3 to 3·5, when the spongy deposit at the cathode is most uniform and pure. With a pH of 4 to 4·5 the electrolyte is less stable, the hydroxides precipitate, and satisfactory sponge iron deposits are formed within a much narrower range of current density (20 to 30 amp/dm^3). With increased acidity (pH 2 to 2·5) the iron deposits in a compact layer and spongy deposition takes place only at current densities of 40 amp/dm^3 and over.

Metal powders and metal powder products. Report of Committee B-9 (*ASTM Preprint* 13, 1960, pp.6) The report lists tentative methods for testing metal powders, and tentative specifications for sintered metal powder structural parts; also full details of a proposed revision of standard methods of sampling finished lots of metal powders.

Porous and compact strip from iron powder A. N. Nikolaev (*Metalloved. Term. Obra. Met.*, 1960, (1), 28–31) The findings of the investigation show that porous and compact rolled powdered iron strip can be produced and that these possess high mechanical properties. The very high properties of the compact strip are due to the complete elimination of pores and the low proportion of non-metallic inclusions in the original powder. The porous strip can be bent and withstands repeated rolling at high reduction ratios. It may be used as the starting material for manufacturing hollow stampings and cutting out a number of components such as filter elements, self-lubricating spring linings, piston rings, etc.

Developments extend market for stainless powders W. L. Batten (*Iron Age*, 1960, **186**, Sept. 1, 64–66) The addition of a lubricant, thereby improving mechanical properties of stainless powders for structural use is described, with details of methods of operation and of various advantages claimed and projected.—S.H.-S.

An investigation of the effect of technical factors on the pressing of iron powders I. M. Fedorchenko and N. A. Filatov (*Voprosy poroshkovoi metallurgii i prochnosti materialov*, **7**, 1959, Ukrainian Academy of Sciences, 105–119) Factors studied included method of preparation and size grading of the powder, temp. of preliminary annealing, effect of atmosphere, state of the working surface of the die, and the type and length of rotation in a ball mill (with or without balls).—A.I.P.

The kinetics of the change in properties during the isothermal sintering of iron powder R. A. Andrievskii and I. M. Fedorchenko (*Voprosy poroshkovoi Metallurgii i prochnosti materialov*, **6**, 1958, Ukrainian Academy of Sciences, 19–28) Regularities in the kinetics were studied. The rate of change diminished with time. This was explained by a slowing down in the rate of sintering and by a reduction in the role of the surface processes in the later stages. Change in properties is not caused only by change in density. All properties studied were sensitive to changes in pore shape. An explanation is given of the regularities observed between properties of porous bodies and density (29 refs).—A.I.P.

Spherical powders find new uses Linde Co. (*Iron Age*, 1960, **186**, Sept. 8, 105) A process for producing spherical powders of pure metals and metal alloys, with particles ranging from 20 to 150 μ, and a uniformity rate of 98%, are described. Six different powders with numerous uses are discussed.—S.H.-S.

FERRITES, CERMETS AND CARBIDES

Self-diffusion of iron in nickel ferrite R. H. Condit, M. J. Brabers, and C. E. Birchenall (*Trans. Met. Soc. ASME*, 1960, **218**, Aug., 768) An investigation was undertaken to test the hypothesis that nickel substituting for iron in magnetite might decrease the rate of spinel growth by reducing the iron mobility. Results are shown in comparison with earlier data on magnetite and zinc ferrites. The roles (three) played by nickel in reducing the oxidation rate of iron–nickel alloys are stated.—S.H.-S.

Sintering of the Ba–Bi ferrite magnet M. Sugimoto and T. Takei (*Sci. Pap. Inst. Phys. Chem. Res. Jap.*, 1960, **54**, June, 212–218) Magnetic properties of a Ba-ferrite magnet are reported to be improved appreciably by addition of Bi-oxide or alkali bismuthates and such additions are claimed to reduce firing temp. in manufacture. The role of Bi-compounds in the Ba ferrite magnet is discussed in connexion with chemical and physical processes involved in its preparation.—S.H.-S.

PROPERTIES AND TESTS

Synthetic methods of material testing (*Schweiz. Arch. Wiss. Techn.*, 1960, **26**, Oct., 373–390) The methods described are either designed to simulate results obtained in service, or are carried out on full-scale components. Examples are given from work carried out by Eidg. Materialprüfungs-und Versuchsanstalt.

Features of material technology in laboratory and practice B. Augland (*Tek. Ukeb.*, 1960, **107**, Aug. 11, 601–608) The necessity both for a study of fundamental principles and for close co-operation between laboratory and user is emphasized. Some factors determining effective strength of metals are discussed, the need for developing test methods from which service behaviour can be predicted is considered, and examples are given from the fields of high temp. service, fatigue, brittle fracture, and microcracking in welds.

Machinery and equipment for materials testing (*Wire*, 1960, April, 43–47) A description of physical testing machines, and equipment for non-destructive testing, shown at the 6th European Machine-Tool Exhibition, Paris, 1959.

A mutual solid solubility scale for metals Y. L. Yao (*Trans. Met. Soc. AIME*, 1960, **218,** Aug., 632–633) A scale on an empirical basis, based on existing data for the mutual solid solubilities of metals in binary systems is presented, as being useful when conflicting values of the two solubility limits are reported in some systems provided the two metals do not form a continuous series of solid solutions.

Evaluation of hoist rope performance H. Bergovitz (*Iron Steel Eng.*, 1960, **37,** Sept., 110–114) An analysis is given of the traction process in modern lift mechanisms, and a description is given of a rope testing machine which simulates service conditions, and of the performance of pre-formed and non pre-formed traction steel rope.

An investigation of the kinetics of the high-temperature reduction of iron–copper alloys I. N. Frantsevich and P. F. Nocharnyuk (*Problemy poroshkovoi metallurgii i prochnosti materialov*, **8,** 1960, Ukrainian Academy of Sciences, 69–74) The kinetics were studied of the reduction of a pseudo-alloy in the temp. range 300–900°C. The kinetic curves of the reduction of the alloy are logarithmic (up to 450°C) and then parabolic (above 450°C). A slight reduction in the electrical resistance to an oxide film at temp. above 600° and the associated increase in the reduction rate is caused by the appearance in the layer of scale of phases with defective structures (FeO and Cu_2O). There is evidence of secondary reactions which lead to the formation of lower forms of oxidized copper (CuO) and elementary copper. **An investigation of the kinetics of the high-temperature reduction of the Fe–Cu–Ti alloys** (75–80) The ternary alloy Fe–Cu–Ti was studied in the temp. range 300–900°C using the method of the continuous weighing of the specimens. The kinetic curves of the reduction of the alloy follow the logarithmic and parabolic laws of the reduction rate. The complex character of the change in the electrical resistance of the scale layer is caused by the appearance of phases with defective structures (FeO and Cu_2O) and by their reduction at higher temp. to pure metals with additional cations of Ti of higher valency which reduce the electrical conductivity of the scale layer.—A.I.P.

Development of improved destroyer escort tail shaft steels S. L. Gertsman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div. Res., & Special Proj. Rep.*, 1960, Jan. 15, 3) Work to improve impact properties has been carried out. A steel resembling AISI 1040 with higher Mn and 0·15%V has been produced and a prototype forging is to be made. **Development for steels for use at low temperatures** (3–5) The effect of Nb up to 0·65% on a plain carbon steel has been studied. The carbide phases have been isolated and identified.

Carbon: strength relationships in 5 per cent chromium ultra-high strength steels J. C. Hamaker jun. and E. J. Vater (*AST Preprint* 80, 1960, pp.27) Effects of 0·2 to 0·5%C were tested in an alloy steel with 5·0%Cr, 1·3%Mo, and 0·5%V in the range −195 to 593°C. After heat treatment, UTS of the order of 116 to 147 t/in² were obtained as C increased. Vacuum melting and secondary hardening are important (32 refs).—J.W.J.

Internal friction of FeAl alloys due to solute atom pairs. Remarks on the theory of the effect G. Biorci, A. Ferro, and G. Montalenti (*AFOSR–TN–60–495; PB* 147501, 1960, Jan., pp.56; from *US Res. Rept.*, 1960, **34,** Sept. 16, 325) The internal friction due to directional short range order in Fe–Al alloys has been studied. At the frequency of about 1 cps the effect appears at about 510°C with a relaxation time corresponding to a process of substitutional diffusion. The intensity of the effect increases rapidly for concentrations above 10%, and then drops to low values in the region of Fe_3Al, where the order occurs. Hence the curve of the intensity of the effect as a function of concentration is, with fairly good agreement proportional to the number of solute Al pairs, as deduced from X-rays results of Bradley and Jay. However, some deviation from ideality seems to be present also at low concentrations.

Comparison of the values of the modulus of elasticity of grey iron obtained by a static and a dynamic method J. Dilewijns (*Fond. Belge*, 1960, **30,** Nov., 293–296) The various methods for determining the modulus of elasticity are briefly surveyed and a detailed description of the dynamic method using the Förster Elastomet and the flexion test is given. The relation between the values of the modulus of elasticity measured by the Electromet and those obtained by the bend test are compared by statistical analysis for a series of grey irons of various compositions, and the results are discussed.—S.H.-S.

Temperature dependence of the elastic moduli of several stainless steels F. Garofalo (*ASTM Preprint* 81, 1960, pp.12) In the temp. range 27–538°C the elastic moduli of three stainless steels, Cr–Mn–N, Cr–Mn–Mo–V–N, and a modified 422, are greater than those of the AISI 300 series, but diminish at higher temp. Poisson's ratio and the shear modulus were also explored. Higher values for Cr–Mn–N steel are attributed to the pinning of dislocation loops by N and C atoms. In the Cr–Mo–Mo–V–N steel, V causes a change in the valency electron charge distribution in the lattice (11 refs).—J.W.J.

The influence of chromium and cobalt on the change in certain properties of iron at high degrees of cold plastic deformation D. Ya. Sirotenko and L. I. Lysak (*Voprosy Fiziki Metallov i Metallovedeniya, Ukrainian Acad. Sci., Kiev*, 1959, (10), 40–45) It is shown that at deformation of 70–98% a marked increase is observed in the microhardness of pure iron as well as of Fe–Cr and Fe–Co alloys. Changes in coercive force and electrical resistance were also observed.—A.I.P.

Damping capacity of cast iron T. Kusakawa and S. Iijima (*Imono*, 1960, **32,** June, 446–452) A paper discussing elastic hysteresis, the Cambridge Torsional Demping Capacity machine, with logarithmic decrement, an attenuator, and the attenuate coefficient of ultrasonic waves is presented.—S.H.-S.

The stress-induced ordering internal friction of iron-rich alloys of iron and aluminium J. C. Shyne and M. J. Sinnott (*Trans. Met. Soc. AIME*, 1960, **218,** Oct., 861–865) LF mechanical damping measurements indicated that the atomic ordering of the Fe–Al system had a marked influence on the stress-induced ordering internal friction. Magnetoelastic damping was encountered, and was reduced by applying a static stress (12 refs).

Some elastic properties of an edge dislocation wall J. C. M. Li (*Acta Met.*, 1960, Aug., 563–574) A detailed elastic theory calculation is given to reveal the stress field of a dislocation wall consisting of a finite number of uniformly spaced edge dislocations of the same slip vector. The interaction of solute atoms is discussed in terms of the dilatational strain field, and the strain energy of a dislocation wall is calculated and compared with that of a set of randomly distributed dislocations to confirm the energetics of polygonization. Finally, some mechanical properties are discussed in terms of the ability of a dislocation wall to resist the penetration of approaching dislocations and its contribution to the brittleness of the material.

A generalized form of the relation $\sigma_t = f(E_0, \Delta)$ in cast irons with a pearlite matrix J. Navarro Alcacer (*Inst. Hierro Acero*, 1960, **13,** July–Sept., 791–794) The author discusses the studies that have been made of this relationship and proposes the equation, $\ln \sigma_t = 2 + 0{\cdot}47E_0\Delta$ (σ_t = tensile strength, E_0 = modulus of elasticity of the cast iron, Δ = Brinell hardness), which describes the action of the graphite on mechanical strength over a wide range of graphite contents (10 refs).—T.S.

Internal friction in quench-hardened low-carbon steel and cold-worked iron T. Ichiyama, M. Kawasaki, I. Kudo, and O. Waki (*Nippon Kinzoku*, 1959, **23,** Dec., 717–721) Three corresponding anelastic effects were found in a quench-hardened plain-C steel containing 0·12%C and cold-worked iron containing 0·019%C. A relaxation peak at 40°C is caused by stress-induced ordering of interstitial solute atoms, and one at 230°C by stress-induced movement of dislocations. A continuous increase in internal friction with temp. after 280°C is caused by coupled relaxations of a network of sub-grain interfaces (24 refs).

On the measurement of interstitial C and N content, and the strain-amplitude dependence of internal friction in commercial steels K. Aoki, S. Sekino, and T. Fujishima (*Nippon Kinzoku*, 1959, **23,** Dec., 696–698) An apparatus for measuring internal friction of square bars vibrating transversely in the range $16–20 \times 10^3$ c/s detects interstitial C and N contents down to 10^{-5} wt·% in low-C steels. Results are given for rolled pure iron and annealed Al-killed deep-drawing steel. The strain-amplitude of internal friction was also measured for both specimens.—K.E.J.

The high-temperature internal friction before the Ac transformation in steels T. Ichiyama and K. Takashina (*Nippon Kinzoku*, 1960, **24,** (2), 101–104) Internal friction curves in 0·85%C steel continue to rise with temp. from ~400°C. The activation energy of the process causing the anelastic behaviour is 59–64 kcal/mol. In recrystallized and tempered steels, the curves shift towards higher temp. with rise of annealing temp. At a given temp. the friction in fully recrystallized and tempered steels exceeds that in steel annealed at above A_{3-1} (17 refs).—K.E.J.

Regarding the nature of the maximum internal friction in steel after heat treatment Yu. V. Piguzov, M. A. Krishtal, and S. A. Golovin (*Fiz. Met. Metallov.*, 1960, **10,** (2), 285–290) The data relative to the nature of the maximum internal friction at 200° in the heat-treated and deformed steel are discussed in the light of the findings regarding the effect of low temperature heat-treatment, quenching, subcritical temp. and cold deformation. Results point to the fact that in quenched and tempered steel the maximum at 200° is also conditioned by the occurrence of certain relaxation processes in the stress system: diffusion of carbon atoms in the residual austenite, migration of the carbon atoms in the dislocation zones, which form owing to the martensite transformation, and the thermal stresses.

Stress relaxation in metals I. A. Oding, V. S. Ivanova, V. V. Burdukskii, and V. N. Geminov (*Chap. VIII of *Teoriya polyuchesti i dlitelnoi prochnosti metallov*, 1959, Metallurgizdat) A detailed review of theories of relaxation illustrated with tests and examples.

The strengthening of austenitic solid solutions F. Eberle, J. H. Hoke, E. J. Rozic, and W. E. Leyda (*WADC–TR–58–28; AD–151161; PB* 131992, 1958, Feb., pp.69; from *Nucl. Sci. Abs.*, 1959, **13,** Dec. 31, 3001) Strengthening susceptibility studies with 10Fe–20Cr–70Ni and 20Cr–80Co by solid solution hardening, complex carbide hardening and intermetallic compound hardening revealed that the nickel base responds most effectively to intermetallic compound hardening with Ti and Al, less to complex hardening and not at all to solid solution hardening.

The effects of solute elements on the strength properties of iron and cobalt-base alloys A. K. Wolff, E. E. Underwood, R. E. Maringer, and G. K. Manning (*WADC–TR–59–258; AD–215432*, 1959, April, pp.68; from *Nucl. Sci. Abs.*, 1959, **13,** Dec. 31, 3001) Factors important in high temp. deformation were investigated in ternary Fe–Cr base alloys. Periodicity of alloy strengthening in cobalt-base binary alloys reveals the most favourable solutes for strengthening, the influence of crystal structure, and the regularity of electronic effects.

Application of the dislocation theory to heat-resistance problems I. A. Oding (*CTS* No.486; Trans. of *Issledovaniya po Zharoprochnym Splavam, USSR*, 1957, **2,** 320–329; from *US Tech. Trans.*, 1960, **4,** July 27, 118; No abstract.

A modification of the Coulomb-Mohr theory of fracture B. Paul (*OOR*–2060.2; 1960, Jan., pp.51; from *Nucl. Sci. Abs.*, 1960, **14,** July 31, 1770) Limitations with brittle materials are noted. A three parameter theory, derivable from two sample tests, is given and tested for cast iron.

The effect of chromium on the activity of sulphur in liquid iron N. R. Griffing and G. W. Healy (*Trans. Met. Soc. AIME*, 1960, **218,** Oct., 849–854) The activity coefficient of S was determined by measuring the values of P_{H_2S}/P_{H_2} in equilibrium with the melts. Cr was shown to have a pronounced negative effect on the coefficient, and its influence was not altered by the presence of appreciable amounts

of C or Si. Up to about 20%Cr this influence can be represented by the equation: $\log f_B^{Cr} = -0{\cdot}019\%Cr$ (10 refs).

Determination of the equilibrium constant of the reaction of hydrogen with oxygen in liquid iron H. Sakao and K. Sano (*Nippon Kinzoku*, 1959, **23**, Nov., 671–674) Data for the equilibrium constant, its variation with temp., and the solubility of O in the presence of Al_2O_3 are given, and shown to agree with reliable published data (28 refs).—K.E.J.

Investigation on the best experimental condition for equilibrating hydrogen with oxygen in liquid iron H. Sakao and K. Sano (*Nippon Kinzoku*, 1959, **23**, Nov., 667–670) Published data on experiments on the equilibrium const. of the reaction of H_2 with O_2 in liquid Fe are reviewed. Errors caused by thermal diffusion are not so large as has been thought. Argon-quenching provides the best sampling method (10 refs).—K.E.J.

Number of 3d electrons in iron S. K. Joshi (*J. Chem. Phys.*, 1960, **33**, Oct., 1261) A letter. The number arrived at is 7·4.

Interatomic distances in FeS_2, CoS_2, and NiS_2 N. Elliott (*J. Chem. Phys.*, 1960, **33**, Sept., 903–905).

Rate of alloying uranium alloys with stainless steel. (Part I. 1800 to 2300°F) R. S. Neymark (*NAA–SR–3278*, 1960, June, pp.31; from *Nucl. Sci. Abs.*, 1960, **14**, Sept. 15, 2157) The rate of alloying between Type 304 stainless steel and metal fuels was investigated at 1800° to 2300°F. The alloying times were determined by experimental couples in vacuum and by short fuel elements with a Na or NaK bond between the fuel and the cladding. The fuels included unalloyed U, U–Mo alloys, and a Th–7·6 wt-%U alloy. Within the stated temp. range, unalloyed U alloys rapidly with the stainless steel, U–10Mo somewhat slower, and Th–7·6U the slowest of the fuels tested. The presence of a thin oxide film on the surface of a U–10 Mo fuel wafer substantially lengthens the time required to form the low-melting Fe–U eutectic, whereas this effect is minor with unalloyed U.—C.F.C.

Investigation of lattice changes in iron and cobalt alloys, with particular reference to the mechanism of sliding deformation. IV T Homma (*Denki-Seiko*, 1959, **30**, (4), 319–329) This section deals with lattice changes $\alpha \rightleftharpoons \gamma \rightleftharpoons \varepsilon$ in Fe–Mn alloys, under the following headings: (1) Summary of information in the literature, (2) preparation of materials for examination, (3) M–A diagram, (4) Effect of cold-working on M_s–A_s diagrams, (5) Relationships between degree of working and extent of change, (6) Microscopically-visible lattice changes produced by cold working, (7) Hardness and reduction in magnitude of the γ-phase, (8) General conclusions (10 refs).

Solubility of oxygen in delta iron E. S. Tankins and N. A. Gokcen (*ASM preprint* 236, 1960, 843–852) Solubility of oxygen in delta-iron has been determined by equilibrium with gaseous mixtures of H_2O and H_2 in the range of 1420–1510°C. Results show that the solubility of O_2 increases with increasing temp. and it may be expressed by $\log [\%O_2] = 12630/T + 5{\cdot}51$.—R.S.F.C.

The solubility of lead in liquid iron A. E. Lord and N. A. Parlee (*Trans. Met. Soc. AIME*, 1960, **218**, Aug., 644–646) Measurements of the solubility of Pb in liquid iron were made at 1550°, 1600°, 1650°, and 1700°C using two different methods, i.e. (1) liquid iron-liquid lead equilibration and (2) liquid iron–lead vapour equilibration.

Thermal stresses in an elastic, work-hardening sphere Chintsun Hwang (*Trans. ASME, J. App. Mech.*, 1960, **27**, Dec., 629–634) Structure is dependent on stress rate and stress history but local stress rate is interrelated with the stress rates of the neighbouring elements directly by the equilibrium condition and indirectly by the compatability condition which governs the strain rates of the neighbouring elements. In this paper, the problem is simplified since the three components of stress deviation can be represented by the same expression modified by different constants. Thus the thermal-stress problem is reduced to a single stress equation. Various examples are given (11 refs).—C.V.

Ship plating loaded beyond the elastic limit A. G. Young (*Trans. Inst. Naval. Arch.*, 1959, **101**, 143–165) The behaviour of panels for ships with a side ratio of 3:1 or more is presented and formulae for load-carrying capacity are developed.

Bonded metal-to-metal shear testing L. R. Lunsford (*ASTM Preprint* 86b, 1960, pp.11) Bonded panel construction is used on all areas of the Convair Supersonic B.58 bomber except where high temp. strength is important. Further developments are limited by lack of knowledge of the properties of bond and joints, especially methods of measuring shear strength. At present, joints should be designed using the theory of elasticity followed by early tests.—J.W.J.

The shear component of ductile fracture K. E. Puttick (*Phil. Mag.*, 1960, **5**, July, 759–762) The two stages in the fracture of a cylindrical test piece of a ductile metal are discussed in the light of the propagation of the tensile stage of the fracture, and the cases of a prismatic crack with wedge-shaped tip and a lens-shaped crack are compared, with the conclusion that a real crack is rarely ideally symmetrical.—S.H.-S.

Factors related to the tensile strength of cast iron G. N. J. Gilbert (*BCIRA J.*, 1960, **8**, Sept., 695–702) The relationship between tensile strength, chemical composition, and section size is considered, together with other factors which affect the tensile strength of cast iron. In particular the effect of eutectic cell size on tensile properties and the mechanism whereby cell size affects tensile strength are discussed. Factors which reduce tensile strength invariably increase the curvature of the stress/strain curve.—S.H.-S.

The tensile properties of type 410 stainless steel deformed before and after martensite transformation Y. Hosoi and K. E. Pinnow (*ASM preprint* 218, 1960, 591–602) Swaging to 57% reduction in area at 800°F increased yield strength and tensile strength without much decrease of elongation. Other treatments giving greater increases at the expense of elongation are given.

Various treatments of melt and S-curve in molybdenum and nickel cast iron (Rept.2) T. Ototani and Y. Tokunaga (*Imono*, 1960, **32**, July, 476–482) The effects of Mg-treatment, vacuum-melting, and an addition of Fe_3O_4 on the S-curve for 0·5%Mo–1·4%Ni cast iron were investigated and the behaviour of the isothermal austenite transformation was studied by the same methods as described in the 1st report. The results of the tests are summarized.

Low temperature flow and fracture tension properties of heat-treated SAE 4340 steel F. R. Larson and J. Nunes (*ASM preprint* 223, 1960, 663–682; also *PB* 161467; digest in *Met. Progr.*, 1960, **78**, Oct., 239, 240) True-stress true-strain tension properties of a heat-treated SAE 4340 steel were obtained at a testing speed of 0·01in/min over a range of temp. from +200° to −196°C. A variety of microstructures, martensite, bainite, and pearlite were studied at several strength levels. The flow stress, strain hardening, fracture stress, and fracture strain, were determined. Analysis of the data has shown that the flow stress at a constant true strain is closely described by a reciprocal absolute temp. function.There are also reported some interesting trends of strain hardening and fracture strain with respect to strength level and testing temp.—R.S.F.C.

Residual tensile stress concentrations and tensilely-stressed cracks versus toughness of heat-treated AISI 4340 steel S. V. Arnold (*WAL–TR* 834.21/1; *PB* 147506, 1960, May, pp.18; from *US Res. Rept.*, 1960, **34**, Sept. 16, 327) By bending standard Charpy V impact specimens over a fulcrum placed against the mouth of the notch, altered specimens were obtained with angles of permanent set ranging from a fraction to several degrees. The metal at the base of the Charpy notch underwent permanent compressive deformation and then, upon release of load, this metal was placed in residual tension by elastic recovery of the specimen. Incipient cracks formed at the base of the notch. Specimens were tested in impact over a range of temp. to determine the effect of such alterations upon energy level and transition behaviour of AISI 4340 steel quenched and tempered to various strength levels.

The effect of carbon content on the notch properties of 43XX-vanadium modified and 5 per cent chromium sheet steels E. P. Klier (*ASTM preprint* 76c, 1960, pp.12) Notch-tension properties of 543 XX V-modified steels containing 0·21 to 0·60%C and two 5%Cr steels with 0·24 to 0·39%C, were measured at from −198 to 29°C for several tempering temp. Attention was given to testing conditions, design of edge notch tension test-pieces and appearance of fractures. For V-modified steels, reduced C tended to increase notch toughness, but the reverse is true of Cr steels. Optimum strength level where notch and yield strength are equal is 78 t/in² for V steels and slightly higher for Cr steels.—J.W.J.

Effect of stress concentration on tensile strength of titanium and steel alloy sheet at various temperatures G. Sachs and J. G. Sessler (*ASTM preprint* 76a, 1960, pp.14) The authors review the history of brittle behaviour of structural materials; seven alloy steels, UTS 85 to 137 t/in², and five Ti alloys were tested to correlate tensile strength with the stress concentration factor K_t, which varied from 1 to 21, varying the root radii of edge notches in sheet test-pieces. The tests were made at room temp. and a more limited series at temp. from 195–527°C. Neither the steels nor the Ti alloys lost strength at low temp. if unstressed, but stressed steels showed sharp transition temp. rising above room temp. with increase of stress concentration (17 refs).—J.W.J.

The properties of high tensile strength cast and wrought steels S. L. Gertsman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 27–28) Cast and wrought specimens of three steels were tested at room and elevated temp. (370–590°C). Effects of tempering on fatigue was also made and the results are explained on a new theory.

A bend test for toughness D. K. Hanink (*Met. Prog.*, 1960, **78**, Oct., 150) A letter, pointing out and correcting an error in the chart in Fig.2 of the article under the above title (*ibid.*, 1960, **78**, Aug.) which omitted to show a sharp break at P_1 load. The corrected curve is reproduced.

Low temperature tensile-hardness correlations of SAE 4340 steel J. Nunes and F. R. Larson (*WAL–TR–320.4/1*, 1960, Feb., pp.18; from *Nucl. Sci. Abs.*, 1960, **14**, May 15, 1111) Vickers hardness (DPH) and tensile strength (UTS) were studied on one heat of SAE 4340 steel as a function of testing temp. Martensitic bainitic, and pearlitic structures of various strength levels were tested in a range of room temp. to −196°C. It was found that these two variables (DPH and UTS) are linear with respect to the reciprocal absolute temp. The various strength levels formed a family of parallel lines. From this result it is possible to derive some simple empirical equations for calculating approximate values of DPH or UTS in the range studied. It was established that for SAE 4340 the room-temp. SAE hardness-tensile strength correlation is reasonably valid over the range studied. A more accurate hardness–tensile strength correlation for this material was established.—S.H.-S.

Low temperature plastic flow and fracture tension properties of heat treated SAE 4340 steel F. R. Larson and J. Nunes (*WAL–TR–834.2/1*; *AD–231700*; *PB* 145890, 1959, Dec., pp.56; from *US Res. Rep.*, 1960, **34**, June 15, 76) A technical report on tests at a speed of 0·01-in/min over a range of temp. from +200° to −136°C, the flow stress at a constant true strain being closely defined by a reciprocal absolute temp. function.—S.H.-S.

Crack propagation tests of high-strength sheet materials: Part III. Low-alloy air-hardening steel J. E. Srawley and C. D. Beachem (*NRL–5348*, 1959, July, pp.15; from *Nucl. Sci. Abs.*, 1959, **13**, Nov. 30, 2708) The results of crack propagation tests using centre-cracked sheet tensile specimens, 0·5 in wide and 0·075 in thick are presented for a proprietary low-alloy, air-hardening steel (0·4%C, Cr–Mo–V) capable of being heat-treated to a tensile yield-strength of at least 230 Ksi.

Investigation of static and fatigue strength of metals subjected to triaxial stresses W. Lehrer

and H. Schwartzbart (*WADC Tech. Rep.*, 58–430; *AD*–206384, *PB* 151594, 1957, Dec., pp.75; from *US Res. Rep.*, 1959, **31,** May 15, 357) Composite brazed specimens of a thin disc of soft metal between cylinders of hard metal were used in various combinations, but significant results were obtained only with 4340 steel base and Ag filler metal. Procedures were developed for satisfactory brazing over a range of joint thicknesses and for the accurate determination of joint-thickness and of tensile and fatigue properties. The results are discussed (12 refs).

Effect of grain size on crack propagation J. J. Gilman (*Acta Met.*, 1960, **8,** Sept., 665–666) A letter. It is shown that the improvement possible by grain-size reduction reaches a limit.—S.H.-S.

Discontinuous phenomenon on load-elongation curves of stainless steels at elevated temperatures G. Shinoda, T. Sano, T. Sakurai, T. Kawasaki, and H. Izumi (*Nippon Kinzoku*, 1959, **23,** Nov., 645–648) Tests up to 800°C were made on austenitic steels. Tensile strength and elongation decreased to 300°C, then remained const. to 650°C. In this range, serrated discontinuities appeared in the load-elongation curves. The microstructure shows the pptn. of Cr carbide along the slip bands; the particles act as barriers to the motion of dislocations.—K.E.J.

Measurement of Kirkendall effect in the iron–chromium system H. W. Paxton and E. J. Pasierb (*Trans. Met. Soc. AIME*, 1960, **218,** Oct., 794–796) Marker movements, checked by a more direct method, indicate that $D_{Cr} > D_{Fe}$ at $N_{Cr} \sim = 0{\cdot}5$; some non-ring diffusion must occur near this combination. D^*_{Fe} was calculated as a function of composition, results agreeing reasonably well with reported measured values (17 refs).

Study and comparison of oblique bending by the old and new theory of plasticity A. Simopoulos (*VDIZ*, 1960, **102,** Oct. 11, 1389) This is an abstract of a thesis dealing with the calculation of the load-carrying capacity of a reinforced concrete beam of rectangular cross-section under oblique bending forces. This calculation was carried out by the old theory of plasticity in which it is assumed that the stress distribution is a straight-line function and by the new theory in which stress distribution in the bending compression zone is thought to be parabolic. Numerical calculation showed that the load-carrying capacity under oblique bending forces is greater by 25–95% when the new theory is used for computation.—T.G.

On the problem of bending and twisting of cold drawn steel wire F. Brass (*VDIZ*, 1960, **102,** Oct. 11, 1392) This is a résumé of a thesis. Bending and twisting coefficients of cold-drawn steel wire were studied as a function of reduction in area and of the galvanizing process. A study of the heat of working involved in bending and twisting is included in the thesis. The results obtained on large-scale tests are summarized.—T.G.

The behaviour of steel wires subjected to bending stresses with special reference to middle strains F. Paolini (*Ing. Mecc.*, 1960, **9,** Oct., 7–16) The application of general Navier theory to different types of bend-stressed steel wires is described. Bend tests facilitate a comparison of theoretical and experimental results. The results agreed only for wires annealed after drawing, when the calculation assumes elasto-plastic behaviour of the material. Substantial disagreement was found in the case of non-annealed drawn wires.

Notch-toughness properties of ship-plate steel as evaluated by the Van der Veen notched slow-bend test E. A. Imbembo and F. Ginsberg (*SSC*–108, 1959, Aug., pp.21) This report describes the second stage of research work on a programme designed to study the notch-toughness properties of semi-killed ship-steel plate over 1 in thick. The details set forth here are the results of tests on the fracture appearance and ductility transition temp. of samples of $\frac{3}{4}$in; $1\frac{1}{4}$in, and $1\frac{3}{4}$in plate, representing two heats of a low C, high Mn semi-killed experimental steel, as determined by means of a notched slow bend test. Observations made during this investigation seem to indicate that the test provides an estimate of the fracture transition temp. similar to that obtained in the Navy tear test.—C.F.-C.

A study of the mechanism of fracture in torsion P. G. Jones and T. J. Dolan (*T & AM rept.* No.97; *AD* 111222; *PB* 146576, 1956, May, pp.46; from *US Res. Rep.*, 1960, **34,** July 15, 77) Tests to determine the influence of the amount of available elastic strain energy on the shear fracture characteristics of several metals are reported and results are presented.

Contribution to the problem of buckling of a straight shaft by simultaneous pressure and torsion H. Leipholz (*VDIZ*, 1960, **102,** Oct. 11, 1392) Mathematical. This is a résumé of a thesis. According to Ziegler, eigenvalues have to be taken into account in the calculation of the buckling behaviour of a rod or shaft if torsion is present as well as pressure. The author develops a formula for this particular case, the solution is based on an analogy with dynamics.

High speed impact test A. Bartocci (*Met. Ital.*, 1960, **52,** Sept., 587–600) Results are given of high-speed impact tests using a round rifle bullet. The impact speeds were 260–70 m/sec, and 415–425 m/sec corresponding to impact energy of 30 kgm and 75 kgm respectively. During rupture almost the total energy of the bullet is absorbed with little differentiation of tenacity for both the above mentioned impact energies. Dynamic impressions show that the dia. of the impression is a function of the impact energy and not of the impact speed.

Notch toughness of ductile cast iron as a function of composition S. V. Arnold (*Techn. Rept. WAL TR* 330/17; *AD*–149956; *PB* 138581, 1957, Dec., pp.19; from *US Gov. Res. Rep.*, 1960, **33,** Feb. 12, 193) Si contents of 3·17 and 2·15% were found to be commensurate with max. toughness in the as-cast and annealed conditions respectively. Max. rupture energies for as-cast and annealed irons over 12 and 14 ft/lb respectively.

Notch toughness of spheroidal graphite high ductility iron castings V. De Pierre and S. Inouye (*NWPW–T–3–59; NAVORD Rept.* 6493; *PB* 161120, 1959, Sept., pp.51; from *US Gov. Res. Rep.*, 1960, **33,** Feb. 12, 193) The effect of material variables and external test factors on the notch toughness of ductile iron was investigated in the light of data from a literature survey (24 refs).

Development of high-strength steels by working of metastable austenite F. R. Morral (*DMIC Mem.* 39; *PB* 161189, 1959, Nov., pp.20) A review is given of the more promising current work on the development of tensile strengths of 340 000 and higher by deformation in the metastable austenite condition prior to quenching and tempering (28 refs).

An investigation of Swift cupping test correlation and the influence of tool and material surface finish on the test results P. W. Whitton and D. R. Mear (*Sheet Metal Ind.*, 1960, **37,** Oct., 743–751) Results for the Limiting Drawing Ratio in Swift cupping tests performed on three independent presses for rimming and stabilized steel, 70–30 brass and Al are presented. The most difficult factor to control was found to be the punch and die surface quality. Recommendations, based on results of an investigation of this parameter, for defining tool surface roughness are given.

Experimental determination of the limiting loads for austenitic steel tubes M. Ya. Aristov and A. V. Ratner (*Teploenergetika*, 1960, (7), 69–76) Experimental data are given for the determination of the limiting loads for tubes of 1Kh14V2M steel when under internal pressure at high temp. and subjected to cyclic bending. The calculated results agree with numerous experimental data.

Impact testing at high temperatures A. J. Bush (*Met. Prog.*, 1960, **77,** June, 98–101) Equipment and test methods are described for testing Izod and Charpy specimens at up to 1400°F.

Comparison and analysis of notch toughness tests for steels in welded structures H. H. Johnson and R. D. Stout (*Weld. Res. Council, Bull. Series*, 1960, (62), July, pp.28) A correlation of the results from different laboratory tests for evaluating notch toughness, in the light of the literature and experimental results (37 refs).

Effect of radius of curvature of the strikers in the notched bar Charpy impact test S. L. Gertaman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 35–36) Tests with strikers of 8 mm and 2 mm radii were used on three steels with V, Mesnager, or keyhole notches. Work is proceeding on effects on transition temp. measurements.

Tensile-impact test reveals best hot working temperature G. B. Heydt (*Met. Prog.*, 1960, **78,** Oct., 65–66) In a method developed by Carpenter Steel Co., Reading, Pennsylvania, hot specimens are broken in a modified Sonntag universal impact machine over a range of temp. The method is simple, rapid, and relatively inexpensive.

Steel. Report of Committee A–1 (*ASTM preprint* 1, 1960, pp.49) The report contains a review of the work of the Committee and the recommendations accepted for new and revised tentative specifications for a wide range of steels, including a recommendation affecting standards, and details of the following: tentative method of test for notch toughness of turbine and generator steel forgings. Tentative specifications for a wide range of carbon and alloy steels, plate, or forgings.—J.W.J.

Fractures caused by explosions and impacts J. S. Rinehart (*Colorado School Mines Quart. Bull.*, 1960, **55,** Oct., pp.155) Transient stress disturbances are defined and velocities of propagation, normal and oblique incidence and abrupt changes in media are discussed; the difference between elastic bodies and fluids is examined. The mathematics of spalling is reviewed and idealized conditions are presented and the effects of interfaces and laminations are considered. The effects of body shape, the changes in the shape of a stress pulse, together with the effect of transient disturbances and spalling in real materials are studied in great detail.—C.V.

Effect of heat treatment in the ferrite–austenite region on notch roughness of low-carbon steels W. C. Leslie, R. L. Rickett, and W. D. Lafferty (*Trans. Met. Soc. AIME*, 1960, **218,** Aug., 699–709) Notch toughness of 0·10%C steels, rimmed or killed, is improved by holding the steel at a temp. just above the Ae_1, followed by air cooling. The improvement can be gained without apparent change in gross microstructure or hardness. The limits of the process have been determined and some possible reasons for the observed effects are discussed. The results appear to indicate that current theories of transition temp. are inadequate.—S.H.-S.

Mechanical properties of chromium nickel steel alloyed with niobium M. P. Braun, B. B. Vinokur, and A. I. Kondrashev (*Izvest. VUZ Chern. Met.*, 1958, (10), 119–124) A steel with 0·35%C, 1·3%Cr, and 1·5%Ni was alloyed with 0·3, 0·7, and 0·9%Nb and tensile, fatigue, and impact strengths were measured as well as susceptibility to embrittlement. Comparison with Mo and W is made. Addition of 0·3–0·4%Nb is recommended and quenching conditions are suggested (20 refs).

The stability of metals under cyclic plastic strain L. F. Coffin jun. (*Trans. ASME, J. Basic Eng.*, 1960, **82,** Sept., 671–682) During the course of an experimental investigation on the effect of cyclic plastic strain on metals, it was observed that under certain conditions materials subjected to cyclic plastic strain showed little stability to simultaneously imposed steady stresses. The present paper describes and interprets some experiments undertaken to learn more about this behaviour of real materials.—S.H.-S.

The effect of residual stresses induced by strain peening upon fatigue strength R. L. Mattson and J. G. Roberts (*Trans. SAE*, 1960, **68,** 130–136) Spring steel specimens (SAE 5160) were heat-treated, pre-stressed, and shot peened prior to fatigue testing. It is concluded that the residual stresses near the surface, and not strain hardening effects are responsible for an increase in the fatigue limit. Fair correlation was found between endurance limit, the distortion energy criterion, and the maximum shear energy criterion of failure using the principle of superposition of residual stress and load stresses.—A.B.M.

Relaxation of residual stresses due to fatigue loading J. D. Marrow, A. S. Ross, and G. M.

Sinclair (*Trans. SAE*, 1960, **68**, 40–48) Steel specimens were deformed plastically and then cycled within a given strain amplitude. The decrease of the mean stress, or relaxation was then noted. It was observed that the greater part of the relaxation takes place during the first cycle and is then followed by an exponential decay law. These tests simulate the relaxation of internal stresses by fatigue and are interpreted in terms of accumulated plastic deformation.—A.H.M.

Application of the cumulative fatigue damage theory to practical problems W. F. Hofmeister (*Trans. SAE*, 1960, **68**, 274–281) The author presents an analysis of the Corten-Dolan cumulative fatigue damage theory. This is applied to predict the total number of cycles to failure for random dynamics loading on chains operating over sprockets. Good agreement was established between the theory and experimental results.—A.H.M.

Fatigue—the problem in relation to welded structures R. P. Newman (*Welder*, 1960, **29**, April–June, 27–33) The conditions liable to give rise to fatigue failure are reviewed. and the appearance of fatigue fractures and the principal factors in the fatigue problem are discussed.—S.H.-S.

Microstructure affects fatigue strength of steel F. Borik and R. D. Chapman (*Met. Prog.*, 1960, **78**, Oct., 222, 224, 226) Digest of 'The effect of microstructure on the fatigue strength of a high-carbon steel' *ASM preprint No.*209, 1960. Experiments are described by means of which it is shown that the fatigue strength of high-C bainite is higher than that of tempered martensite, in the hardness range Rockwell C 40–61; below C 40, the tempered martensite structure is slightly harder.

A relation between the critical alternating propagation stress and crack length for mild steel N. E. Frost (*Proc. IME*, 1959, **173**, (35), 811–836) Fatigue tests have been carried out on mild steel specimens containing edge cracks of various lengths and the alternating stress just insufficient to cause the cracks to grow obtained. It was found that the relation between this critical alternating stress σ and the crack length δ was given by $\sigma^3\delta$ = constant. By means of this relation is was possible to correlate a wide variety of hitherto unrelated notch fatigue data.—R.S.F.C.

Theory and test results on the fatigue of metals F. Stuessi (*Amer. Soc. Civ. Engs., Structural Div. J.*, 1959, **85**, Oct., 65–90; from *Brit. Railways Monthly Rev. Tech. Ref.*, 1960, **10**, Feb., 10) This paper presents an empirical fatigue relationship between the mean stress and the alternating stress of a cycle; five material characteristics; and the resulting number of cycles to failure. The influence of rate of cycling, of strain-hardening, and of stress concentration is considered separately.

Fatigue crack propagation S. L. Gertsman (*Canad. Dept. Mines Techn. Surv., Phys. Met. Div., Res. Special Project Rept.*, 1960, Jan. 15, 31) Work on mild steel is outlined.

Fatigue properties of some high-strength steels H. E. Frankel, J. A. Bennett, and C. M. Carman (*ASTM preprint* 65; 1960, pp.8) Rotating beam fatigue properties (10^8 cycles) of 18 high-strength steels, above 100 t/in^2, were investigated. Steels with less than 0·4%C had maximum fatigue strength at lowest tempering temp., 177–204°C; high-Si steels (1·5%Si approx.) retained maximum fatigue strength up to 315°C tempering temp. Subsurface nucleation of fatigue cracks was prevalent with best fatigue properties. Cu steels (1–2%Cu) had the best fatigue strength-yield strength ratio.—J.W.J.

Fatigue data on precipitation-hardenable stainless steels R. J. Favor, H. J. Grover, W. P. Achbach (*DMIC Memo.* 46; *AD*–234805; *PB* 161196, 1960, March, pp.16; from *US Res. Rep.*, 1960, **34**, Sept. 16, 325) (No abstract).—C.F.C.

The effect of microstructure on the fatigue strength of a high carbon steel F. Borik and R. D. Chapman (*ASM preprint*, 209, 1960, Oct. 17–21, 447–463) SAE 51100 was used and bainitic and martensitic states were compared at equal hardnesses in the range 36–61 Rc and microstrains were found from the width of the (211) line. The distribution and morphology of carbide particles appears to be the cause of the differences in fatigue properties.

The causes of the reduction of fatigue strength of steel in zones of contact I. V. Kudryavtsev, N. M. Savvina, and L. M. Rozenman (*Metalloved. Term. Obra. Met.*, 1960, (7), 3–7) The causes of the reduction in fatigue resistance of steel components at the zones of contact are the simultaneous action of stress concentrations, electro-erosion damage to the surface, mechanical wear of the contact surface and fretting corrosion. The action of any one of these factors may vary under different conditions and is determined by the material of the contact surfaces and the conditions of loading.

Fatigue of ball bearing steels I. Uchiyama, A. Hoshino, and M. Ueno (*Trans. Mat. Res. Inst. Met.*, 1960, **2**, (1), 6–12) A report on the fatigue phenomena of ball bearing steels. Flaking and cracks caused by rapid life test were observed by the optical and electron microscopes. Results were as follows: (1) When the test was stopped before flaking, the track surfaces were in good condition and no crack was apparent. (2) Cracks in the flaking hole extended down to the inside from the hole in two directions. (3) In the shape of section of the flaking, the depth of the hole was shallow in the side of the rolling direction, and deep on the other side. Problems arising from these results are discussed.—S.H.-S.

The effect of work-hardening on the tendency to deterioration during thermal fatigue Ya. B. Fridman and V. I. Egorov (*Metalloved. Term. Obra. Met.*, 1960, (7), 27–30) Cyclic heating and cooling reduce the strength both of hardened and of annealed 1Kh18N9T steel. The tendency to deterioration (the reduction of the useful strength and plasticity) depends on the upper temp. of the cycle and on the number of cycles. A considerable reduction in strength and plasticity results from cyclic heat loads. Strictly speaking, temp. has an insignificant effect on the mechanical properties of the steel. A prior work-hardening with a small number of cycles does not exert appreciable influence on the resistance of steel to the action of heat, but after a certain critical number of cycles, depending on the upper temp. of the cycle, the resistance of steel to the action of heat diminishes after work-hardening more than after annealing.

Strength of structural alloys under rapid heating and loading J. R. Kattus and D. W. McDowall jun, (*ASTM preprint*, 71, 1960, pp.12) The tensile and creep properties of stainless steels 301, 304, and PH 16–7Mo, and of Nibase sheet René 41, Inconel X, and Nimonic 90 increase with increase in rate of loading at high temp. The stainless steels are stronger than the Ni alloys up to 538°C but at higher temp. the reverse is true. Cold rolling of certain stainless steels at sub-zero temp. increases their short-time strength. At low temp. and for short times at moderately higher temp., cold-rolled structures are stronger than the precipitation hardened condition.—J.W.J.

Analytical approach to the study of the effect of small cavities on fatigue strength R. E. Peterson (*Nondestr. Test.*, 1960, **18**, May–June, 193–194) A study of the main variables to be considered in respect of small cavities including shape, orientation with respect to stress, proximity to each other, absolute size, and material containing the cavity, is presented and discussed.—S.H.-S.

Resistance of steel components, chemically hardened at high temperature, to asymmetric loading cycles D. S. Elenevskii and L. M. Shneerson (*Vestnik Mashin*, 1960, (10), 17–22) The condition of the surface-hardened layer has a decisive influence on the fatigue strength of components working under asymmetric loading cycles. It had been shown earlier during investigations into the effect of the final treatment of cemented gears on their resistance to alternate and contact loads, that shot peening neutralizes the drop in the resistance of gears, caused by grinding and residual stresses. Shot peening prevents fatigue flaking on the profiles of damaged gears. Electrolytic polishing increases the quality of the surfaces, also increasing the resistance to erosion. Experiments here detailed confirm that electrolytic polishing increases the fatigue limit of cemented components under intermittent cycles by from 5 to 35%.

Stress relaxation and creep considered as processes of viscous flow N. S. Fastov (*Doklady Akad. Nauk.*, 1960, **130**, (1), 64–67) A likely interpretation of the findings of a mathematical analysis of the problem is that in a metal subjected to shear stress, viscous flow (self-diffusion relaxation) occurs; in case of constant deformation as a result of the removal of the stress, and in case of constant stress as a result of creep. During viscous flow some atoms or groups are displaced from certain positions to others and, in the process, surmount the potential barriers, the height of which are equivalent to the time of relaxation.

Steady-state creep of a thick-walled cylinder under combined axial load and internal pressure I. Finnie (*Trans. ASME, J. Basic Eng.*, 1960, **82**, Sept., 689–694) Equations are developed for prediction of steady-state creep stresses and strain rates in a thick-walled tube under combined internal pressure and axial load. An analytical solution of the equations, in closed form, is not possible, but numerical solutions to the equations are tabulated for various values of the variables. For values of the variables other than those tabulated interpolation is usually adequate. If this is not the case, a trial method of calculation is presented which uses the tabulated solutions as a starting point. Simple approximate solutions, which apply for the cases in which the additional axial load is small or large relative to the axial load due to internal pressure, are also given.

Unisteel multi-specimen creep testing machine Distington Eng. Co. Ltd (*Machinery*, 1960, **97**, Dec. 28, 1467–1468) This applies loads ud to 3 t and is designed to enable either four high-sensitivity or 12 stress-to-fracture tests (or any combination of these) to be carried out with one furnace and one temp. controller. Within the furnace there is a stainless steel heat-sink with four compartments, thus providing complete isolation of a loading system and its test-pieces. Four meters, one for each loading station, provide a time record for each individual test; when a test-piece fractures, the corresponding meter automatically stops.

Measuring accuracy in creep tests. Part II. Influence of thermal stresses A. Mellgren (*WADC Techn. Rep.*, 59–78, Part II, *OTS* 161356, 1959, Oct., pp.54) The thermal stresses induced in cylinders and plates by non-uniform surface temp. are calculated, and the relations of thermal stresses to creep determined for cylindrical and sheet creep specimens (10 refs).

Vacuum furnace for creep-rupture testing T. F. Hengstenberg and E. F. Vandergrift (*Met. Prog.*, 1960, **77**, June, 94–97) The testing chamber described can operate up to 2700°F at a pressure as low as 2×10^{-5} mm. It has low power requirements, ease of test assembly, and adaptability to conventional creep and stress-rupture testing machines.

Occasional fractures of railway axles below wheel hubs A. De Anda (*Rail. Steel Topics*, 1959, **5**, Autumn, 15–18) The author, an engineer on the Administration of the Uruguay State Railways, discusses the causes of axle failure, with particular reference to experience on his own railway, and refers to fretting corrosion, stressing, crack formation, and detection.

The causes of the slow decay of high-strength steel bolts O. L. Bendryshev, V. V. Pet'ko, and Ya. B. Fridman (*Vestnik Mashin*, 1960, (7), 6–10) These causes may be divided into different groups, for example: unsatisfactory construction; unsuitable material; faulty finish; faulty heat treatment; incomplete rinsing after plating; faulty tightening; unsuitable service conditions, etc. These groups are analysed individually and recommendations are made.

Hardenability bands for steels 4320-H to 4718-H (*Met. Prog.*, 1960, **47**, Oct., 132B) Data sheet for steels 4520-H, 43xx series, 43xx-H series, and 4718-H.

Where to use microhardness testing V. A. Lysaght (*Met. Prog.*, 1960, **78**, Sept., 121–125) Several applications are described of the method, including the testing of small parts, thin sections, and microconstituents.

High strength steel: effect of varying composition to a target hardenability, and an experimental silicon-rich boron-treated low alloy steel S. V. Arnold (*WAL TR* 320.1/1; *AD*–226966; *PB* 161007, 1959, Oct., pp.39; from *US Res. Rept.*, 1960, **34,** Sept. 16, 326) The tensile, notched-tensile, and impact properties of a number of experimental 0·30%C–Ni–Cr–Mo steels, made to target composition of calculated 15″DI hardenability, were determined after quenching and tempering at 450°F. Tensile, notched tensile, and impact properties of an experimental 0·33%C–Si-rich B-treated steel with moderate amounts of Cr and Mo when quenched and tempered within the range 450–700°F, were exceptionally good.—C.F.C.

The determination of hardness in steels from the breadth of X-ray diffraction lines R. E. Marburger and D. P. Koistinen (*ASM preprint* 228, 1960, 743–752; digest in *Met. Prog.*, 1960, **78,** Oct., 218, 222) The broad asymmetrical nature of martensite diffraction lines has in the past been the source of great difficulty in X-ray diffraction studies of hardened steel. It is shown that by utilizing the increase of martensite line breadth with hardness it is possible to make rapid non-destructive surface hardness measurements. A simplified method of measuring the breadth of the broad martensite lines is described. This method employs the three-point parabola fitting technique that is used in the measurement of residual stresses in hardened steels. Thus, surface hardness may be calculated using the same data used in making a residual stress determination.

Effect of heat treatment on the hardness and microstructure of 30 per cent chromium cast iron J. W. Boyes (*BCIRA J.*, 1960, **8,** Sept., 726–741) Results of one stage of an investigation by BCIRA on cast irons with about 30%Cr are reported. Eight compositions nominally 27–33%Cr with 1–2%C and 1–2%Si were examined, being given a two-stage heat treatment; first at 500°, 700°, or 1000°C for 1 or 48 h, followed by water quenching, air cooling, or furnace cooling; secondly by a 'tempering' treatment at 400° or 600° for 4 or 48 h followed by air-cooling, hardness determinations and microscopical examinations being made after each stage. Certain irons were martensitically hardened after treatments at 1000°C, and results illustrated the importance of Cr, C, and Si contents when considering the effects of high temp. holding. Most increases in hardness not associated with any microstructural change were related to '475°C embrittlement'. It was found that martensite tempered fairly readily at 600°C and that increases in hardness attributable to '475°C embrittlement' were also lessened by treatment at this temp., tempering at 400°C having little or no effect in either case. Other increases in hardness thought to be due to elevated temp. temper-hardening were little affected by treatments at 400° or 600°C, and further investigation of this type of hardening is considered necessary.—S.H.-S.

The structure and hardness of alloys of iron with low carbon and nickel contents R. Vogel and G. Volpato (*Arch. Eisenhütt.*, 1960, **31,** Nov., 687–690) Experiments were carried out on iron alloys containing up to 0·6%C and 4%Ni, and given various heat treatments. The results are discussed, with particular reference to the formation of Cohenite in meteoric iron.

Penetration of hard-steel spheres into plane surfaces W. Goldsmith and P. T. Lyman (*J. App. Mech.*, 1960, **27,** Dec., 717–725) An experimental investigation under static and dynamic conditions, the latter involving the Hopkinson-bar technique, with max. elastic strain rates of 500 sec^{-1}. Excellent correlation was obtained between the measured permanent crater dia. at the contact point and that calculated from the strain-gauge data by means of an equation which treats the bar as a one-dimensional member. Static and dynamic force-indentation curves, Hertz law of contact, and a relationship based on the concept of constant flow pressure in the plastic regime were compared and are discussed in detail (36 refs).—C.V.

Effect of work hardening on the deformability of 1Kh18N9T steel A. V. Stanyukovich (*Metalloved. Term. Obra. Met.*, 1960, (7), 7–14) Composition of the steel: 0·12%C, 1·0%Mn; 16·98%Cr, 10·96%Ni; 0·01%S, 0·018%P; 0·66%Si and 0·5%Ti. Quenched from 1050° and tempered 3 h at 680°. Assessment of deformability was carried out in tests at a constant rate of deformation as explained in *Zavods Lab.*, 1959, (9), by the same author. A rapid reduction in the deformability of the material as a result of work-hardening is clear from a comparison of the diagrams given. 18% hardening reduces this property greatly, and both temp. range and rate of deformation, resulting in failure of the material with a relative elongation of less than 1%, are relatively very wide (500–700° at rates of 10^{-2}% per h and lower).

The effect of cold work and temperature on strength and structure of steel P. Shahinian, M. R. Achter, and W. A. Pennington (*ASM preprint* 234, 1960, 817–836) AISI 4140 was examined and physical, optical, electron-microscopical, and X-ray studies were made with or without deformation. Two opposing effects of cold work are postulated. (See next abstract.)

Cold work and temperature affect steel G. H. Enzian, P. Shahinian, M. R. Archer, and W. A. Pennington (*Met. Prog.*, 1960, **78,** Oct., 230, 232) Digest of preceding. Investigations are described with the object of explaining the fact that cold deformation in amounts of <about 12% lowers the creep resistance at temp. below the recrystallization range, whereas higher amounts of prior deformation increase the elevated temp. strength. A softening effect obtained at small deformations and a hardening effect at large deformations with specimens of low-alloy steel AISI 4140 was attributed to the soln. of fine carbide particles and to lattice strains respectively.

The effect of aluminium on strain ageing and internal friction in low carbon steel F. H. Laxar, J. W. Frame, and D. J. Blickwede (*ASM preprint* 224, 1960, 683–695) Steels with 0·04 and 2·36%Al were used and evidence of C–Al interaction was found. Diffusivity and strain-ageing are effected.

Plastic and anticorrosive properties of cold-rolled annealed type 1Kh18N9T sheet steel V. K. Barzii (*Stal'*, 1960, (12), 1134–1135) After annealing 2 h at 850°C this steel exceeds the requirements of GOST 5582–50. Loss in bonding HNO_3 is very similar after annealing and after quenching from 1100°C. High heat tempering increases the losses of hardened but not of annealed sheet. Annealing can be used to reduce the Ti content required and changes in the GOST specification are suggested.

Influence of strain ageing on the processes occurring in the alternating stressing of steel H. Schenck, E. Schmidtmann, and H. Kettler (*Arch. Eisenhütt.*, 1960, **31,** Nov., 659–669) The processes taking place during the alternating stressing of an unalloyed 0·22%C steel were examined by determining the Young's modulus and damping in the kilocycle/sec range. With bending agent stresses near the fatigue limit damping rises to a value characteristic of each load. The mechanism of this increase is explained in terms of dislocation concentration, and it is also shown that a corresponding decrease in the Young's modulus is obtained. The results obtained are consistent with the theory that the fatigue fracture process can be described by dislocation movements (61 refs).

Relation between the artificial ageing of technical iron and the period of preliminary natural ageing K. M. Pogodina-Alekseeva (*Metalloved. Term. Obra. Met.*, 1960, (2), 7–10) The change in properties with artificial ageing, depends, in addition to the time interval between hardening and heating for ageing, on the schedule of the ageing operation. The data established by many investigators who have not taken this into account cannot be considered reliable. The efficacy of artificial ageing depends also on the period of storage after hardening. For technical iron, artificial ageing at 100° is most effective for a holding time of 24 h. The artificial ageing curves for this iron have two maxima for hardness and consequently two minima for plasticity. This confirms the occurrence of two different strengthening processes during ageing.

Brittle fracture S. L. Gertsman (*Canad. Dept. Mines Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 29) Tests on 'B' quality and HY 80 high-strength steels are recorded.

Preliminary studies of brittle fracture propagation in structural steel W. J. Hall, W. G. Godden, and O. A. Fettahlioglu (*SSC*–111, *PB* 161325, 1958, May, pp.86) Initial research work is described on a program concerned with the propagation of brittle fracture in wide steel plates. The plates are cooled with dry ice, loaded, and fracture initiated by impact. Results are reported and discussed (17 refs).

Hydrogen brittleness of steel during cathodic polarization in sulphuric acid S. M. Beloglazov and M. I. Polukarov (*Zhurn. Prikl. Khim.*, 1960, **33,** (2), 389–397) The changing mechanical properties of steel can best be investigated on a wire specimen in torsion and cyclic bending tests. The mechanical properties of steel change little in cathodic polarization in commercially pure H_2SO_4, but change considerably with small additions of SeO_2 or As_2O_3. The present experiments also confirm the action of catalysts on the hydrogenation of steel as observed earlier by other methods. A comparison of the mechanical properties with the magnitude of the cathode potential justifies the conclusion that in the absence of catalysts the penetration of H_2 into steel is atomic and depends on the H_2 overvoltage. In the presence of catalysts H_2 penetrates into steel as protons and the rate of its penetration also depends on the H_2 overvoltage.

Development of brittleness in steel during anti-corrosion nitriding I. E. Soloveichik and M. L. Finkel'shtein (*Metalloved. Term. Obra. Met.*, 1960, (7), 52–54) Since the metal for the manufacture of many components must first be nitrided as a protection against corrosion, it should be borne in mind that low carbon steels of types 10 and 20 should first be normalized from 800–840° or quenched in water or oil from 800–840° before nitriding. Type 45 steel must first be treated by quenching in water from 840° and tempering at 650°, for 1 h.

The increased brittleness of the nitrided layer of 38KhMYuA steel N. A. Fertik (*Metalloved. Term. Obra. Met.*, 1960, (3), 13–17) The brittleness of the nitrided layer, as determined in tests with the diamond pyramid, may be taken as an index to the tendency of this layer to form roughnesses in grinding. The greater the stresses of the removal of a layer by grinding, the greater the probability of the formation of these. With an increase in the hardness of the core of the component made of nitrided steel the quantity of nitrogen increases, as well as the compression stresses in the layer which increase brittleness. The reduction in the brittleness of the nitrided layer observed with increasing temp. is related to a decrease in the compression stresses.

Effect of induction on 500° embrittlement A. Nakashima and J. E. Libsch (*ASM preprint* 229, 1960, 753–764) Tempering in the embrittlement range giving little decrease of notch impact resistance at ordinary temp. may greatly reduce endurance under severe working conditions. Rapid tempering (in the order of sec) practically entirely suppresses the effect.

Circular-patch test for evaluating armour crack susceptibility L. E. Poteat and R. W. Jones (*WAL TR* 710/1075; *PB* 161822, 1960, May, pp.37; from *US Res. Rept.*, 1960, **34,** Sept. 16, 326) An investigation was conducted to determine the effect of different procedures on the effectiveness of the circular-patch test specimen in the evaluation of plate crack susceptibility and to determine conditions suitable for a standard test. A test procedure was selected and used on several different heats of armour steel. Evaluation of these heats by this procedure placed the heats in the correct order of crack susceptibility as determined from the known fabrication history of the heats.

Selected references on brittle fracture D. Owens and L. Doss (*DMIC memo.* 55; *PB* 161205, 1960, May, pp.65; from *US Res. Rep.*, 1960, **34,** Sept. 16, 324) The purpose of this bibliography is to bring together the results of past and current studies of the subject in view of its renewed importance as an obstacle in the

missile and space programs. The references have been categorized and cross-referenced as testing techniques; low-temp. fracture; fracture of welded structures; influence of processing variables other than welding; temper-brittleness; H_2 embrittlement; influence of composition on brittle fracture; ductile-to-brittle transition; stress-corrosion cracking; fundamental studies and status of research; fracture of non-ferrous materials; design considerations; case histories; and methods of circumventing brittle fracture. This collection of references is not complete and will be revised and expanded as the acquisition of new references makes the need apparent.

Influence of thermal cycling on the brittle transition temperature of low-carbon steel H. Majors jun. (*OOR Rept. No.* 1230.3; *AD*-146076; *PB* 145861, 1957, Oct., pp.21; from *US Res. Rept.*, 1960, **34,** Sept. 16, 326) Grooved tension impact specimens of two steels were subjected to 300°–1000°–300° or to 1000°–1500°–1000°F, the former cycle produced no change in hardness, but cycling through the critical point lowered transition temp., while cycling in the region of 300–1000°F tended to broaden the range of temp. transition from brittleness to high ductility.

Effects of alloying additions on hot cracking of austenitic chromium–nickel stainless steels F. C. Hull (*ASTM preprint* 78, 1960, pp.20) To provide a basis for stainless steel electrodes with improved resistance to hot cracking, 18 alloying elements were added to an austenitic cast steel, 16%Cr–20%Ni, and very low C and N_2, and tests on 69 steels were carried out. A design for a cast pin test is shown and N_2, Mn, Mo, and W were found to decrease susceptibility to hot cracking, while 14 other elements were placed in order of tendency to increase it. Both air and vacuum melts are used and microstructures are correlated (32 refs).

Studies of the strain distribution in wide plates during brittle fracture propagation S. T. Rolfe, T. M. Lynam, and W. J. Hall (*Ship Structure Com. Rep. SSC* 118, 1959, Dec., pp.64) This report summarizes the results of a series of tests made as a part of the study of the propagation of brittle fractures in 6 ft wide steel plates. All plates were tested at an average net applied stress of 19000 psi, a temperature of about −10°F and an impact energy of about 1000 ft/lb, which made it possible to superimpose the test data and obtain contours of strain on the surface of the plate for a propagating fracture. Contours of both the maximum principle strain and strain measured by vertically oriented gauges for various lengths of crack are presented in this report. A study of all the applicable data from earlier tests made as a part of this program indicates that the strain contour data presented here are also representative of the data from these earlier tests. The studies indicate that for the particular specimen geometry and associated test conditions, the strain field associated with the tip of the advancing fracture remains essentially unchanged after traversing about one-third of the plate width and extends only about 8–10in ahead of the crack tip.

Assessing the tendency of steel to brittle failure from its reaction to burning from electrodes M. M. Kraichik and N. V. Pashkov (*Svaroch. Proizv.*, 1960, (8), 6–9) A method is explained for assessing the sensitivity of steel to burning, by means of the critical temp. for brittleness, as determined from impact tests on 12 mm × 8 mm × 55 mm notched specimens (since the burning effect may be equated to notching). It is possible to eliminate the damaging effect of the burn by grinding away the burnt places for a depth of at least 0·7 mm. Among all the steels investigated, 10KhGN, 09G2, and M8t3 as well as 14G2 are most susceptible to burns.

The change in mechanical properties during the heat-treatment of Te–Fe alloys V. N. Gridnev, V. I. Trefilov, and A. S. Drachinskii (*Voprosy Fiz. Met. Metalloved.*, 1959, (9), 82–88) Te–Fe alloys can be used as a high-strength structural material. The best tempering temp. is 450–600°C, which ensures a high degree of ductility and sufficient strength. More than 1·8%Fe apparently causes embrittlement as the result of the appearance of the Ω-phase.—A.I.P.

The amplitude-dependent damping of steel, its causes and their relationship to brittle fracture susceptibility G. Müller-Vogt (*VDIZ*, 1960, **102,** Sept. 1, 1204) Experimental equipment for investigating this relationship is described, and the results obtained with four steels discussed.

Wear-resistance of carbon steels with various types of structure A. A. Soroko-Hovitskaya (*Trenie i iznos v Mashinakh*, 1959, **13,** *Akad. Nauk.*, 5–18) The effect of heat treatment and of the structure of carbon steel was studied in relation to its resistance to abrasive wear. Most resistant was martensitic steel after quenching without tempering. Resistance of hypoeutectoid steels increased with higher carbon contents. Apparently an increase in carbide content in steels increases resistance. Lamellar pearlite was slightly more resistant than granular pearlite. Slight tempering after quenching had no beneficial effect. Structure was not such a good guide to wear-resistance as hardness, and the belief that steel with a troostitic structure is more wear-resistant than one with a martensitic structure was not confirmed.—A.I.P.

Structure and erosion resistance of steel surfaces after phosphatizing I. M. Lyubarskii, A. P. Lyubchenko, and K. S. Gerasimenko (*Metalloved. Term. Obra. Met.*, 1960, (3), 18–21) Phosphatizing increases the general resistance to erosion of the friction surfaces, which is determined by the quantity of erosion products in the grease and transferred to the contact surface. The effect of phosphatizing is greater the lower the hardness of the material. The increased resistance of the surface to erosion after phosphatizing is due to the change in the physico-chemical properties of the friction surface, which bring about a reduction in the tendency of the material to seizing at the points of contact.

Testing the wear-resistant austenitic manganese irons V. B. Lyadskii (*Lit. Proizv.*, 1960, (9), 36–38) Five experimental melts were produced in electric furnaces of which three were of austenitic irons and two of high strength spheroidal graphite iron. A sixth melt, of sulphur iron, was produced in a cupola. The composition of the burden for each melt and also the chemical compositions and the mechanical properties of the resulting irons are tabulated.

The wear of cast crankshafts for the 'Volga' motor car E. M. Shkol'nikov and N. M. Rudnitskii (*Lit. Proizv.*, 1960, (8), 40–41) Different irons were examined: Mg irons inoculated with varying proportions of Mg and Fe–Si, Ce irons inoculated with an alloy of Fe–Si, and Mg and forging irons inoculated with Bi and B. Crankshafts cast in Ce iron have a lower resistance than those of Mg irons.

Study of the wear-resistance of isothermally heat-treated cast iron K. Ogawa (*Imono*, 1960, **32,** July, 490–496) A study of comparative sliding wear upon cast iron isothermally treated between that manufactured by General Motors, USA, Meehanite cast iron, acicular cast iron, Ti-eutectic graphite cast iron, Canodular graphite cast iron, engine cast iron of ILO Germany, and the cast iron which was isothermally heat-treated, in structure of abrasion and amount of wear is presented. Tests were made of lubricating abrasion and paraffin–60 spindle oil was used as lubricant throughout. The results of the tests are recorded.—S.H.-S.

Metal wear by scoring J. H. Olson and R. D. Chapman (*ASM preprint* 204, 1960, Oct. 17–21, 359–379) Score loads have been determined for a variety of ferrous-ferrous and ferrous–non-ferrous combinations by progressively loading lubricated reciprocating samples until scoring occurs. For two hardened steel surfaces, the score resistance increases hyperbolically as the average finish improves from 60 to 38 μin. It is shown that score temp. are constant and that smoothly finished samples do not score until high loads are attained because they remain comparatively cool Furthermore, higher score loads can be attained and score damage minimized by utilizing an Al base, rather than steel, under hard-plated surfaces to enhance the thermal conductivity and prevent loss of the oil film. Data reported agree well with the mechanism of scoring proposed by Crook and Shotter.—C.F.C.

Effect of sulphurizing on wear of antifriction malleable cast iron Ya. F. Lifshits (*Nauch. Doklady Vyssh. Shkoly. Metallurgiya*, 1959, (2), 221–223) Tests showed no improvement at moderate pressures and temp. At higher pressures and temp., with lubrication and with a rolling frictional component, wear was reduced.

Wear evaluation tests on ploughshare materials S. L. Gertsman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res. Special Project Rept.*, 1960, Jan. 15, 34) Tests on cultivator teeth and ploughshare points with eight materials are in progress.

Measurement of gear wear by activating wear particles in the lubricant H. D. Briggs and J. F. Coultry (*Nuclear Engineering and Science Conference*, 1959, April 6–9, *Preprint V*–75, pp.16) The gear was directly activated by irradiation and rate of transfer to lubricant was observed.

The resistance of stainless steels to erosion under conditions of friction with lubricating oil B. Kh. Somin and S. L. Matskevich (*Trenie i Iznos v Mashinakh*, 1960, **14,** *Akad. Nauk*, 185–201) A description is given of the lubricating oils and coats of varnish used. The behaviour of carbon and stainless steels, under conditions of dry friction and of friction with lubricating oil, was compared. The effect of the Cr content and of certain methods of surface treatment on the amount of scratching load were studied (13 refs).—A.I.P.

An investigation with the jamming of steel during testing on a roller machine V. V. Meng (*Trenie i Iznos v Mashinakh*, 1960, **14,** *Akad. Nauk*, 222–239) The method of investigation and the installation used are described. The relationship between the jamming load and slipping speed and the contact temp. at the moment before jamming were studied. Experimental data are discussed.—A.I.P.

Spark testing W. M. Gladwin (*Rail. Steel Topics*, 1959, **5,** Autumn, 22–31) Reprint of an article which appeared in **2,** (3), of 1954, and brought up to date, which described a quick, reliable, and non-destructive test for checking the composition, and particularly the carbon content, of any or every unit of steel in a given batch, the virtue of this test being that by this means a mix in qualities is formed which might otherwise go undetected. A series of tests of different varieties of steels, accompanied by magnified pictorial illustrations of different types of spark arising from them, is presented.—S.H.-S.

Nondestructive testing of steel and steel products W. A. Black (*Nondestr. Test.*, 1960, **18,** May–June, 185–190) A review of testing instrumentation with descriptive details.

Recent advances in new areas of nondestructive testing H. A. Elion (*Nondestr. Test.*, 1960, **18,** May–June, 180–182) Recent advances in ultrasonics, X-ray fluoroscopy, electron probe microanalysis, and radiofrequency spectroscopy, particularly electron spin resonance spectroscopy, are described.—S.H.-S.

Orientation and scope of the present nondestructive testing field D. W. Ballard (*Nondestr. Test.*, 1960, **18,** May–June, 177–179) A short address giving a brief survey of the field with wide parameters.—S.H.-S.

The development of non-destructive testing of welds W. J. Kaufman (*Lastechniek*, 1960, **26,** Sept., 153–165) This is a memorial lecture for Mr L. van Ouwerkerk, former Director of the Roentgen Technische Dienst in Rotterdam. It embodies a survey of the development of non-destructive weld testing in Holland since 1937, the year RTD was started. The article carries a large number of typical illustrations (with English captions) including much apparatus for this purpose developed by various international organizations.—F.R.H.

The place and value of non-destructive testing during manufacture L. van Ouwerkerk (*Metalen*, 1960, **15,** Sept. 30, 310–314) The author reviewed the development of non-destructive testing from the foundation in Holland of the Roentgen Technische Dienst at a time when manufacturers were uncertain as to its value in their particular industries. Subsequent progress has justified the inauguration of such a service which, in the light of further technical progress, has had to be

expanded to include magnetic, ultrasonic, penetration and even some forms of eddy current testing. The author also advanced the idea of closer co-operation between manufacturers and operators of plants especially in view of the advent of nuclear reactor construction with its inherent risks in the event of breakdowns attributable to unsuspected flaws in the materials of which they are constructed. He finally advocated the formation of an independent quality control organization to be run for the mutual benefit of manufacturers and users alike.—F.R.H.

Notes on simulative service testing B. Eichler and A. J. Owen (*Trans. Brit. Ceram. Soc.*, 1960, **59,** May, 149–177) Testing under actual conditions of use or even under more severe conditions gives valuable data supplementing standard tests. Heating rate of silica bricks for use in OH roofs, spalling, slag attack, and hot abrasion testing, all under simulated conditions, are described.

Electromagnetic control testing of lifting cables for mines P. Teissier (*Rev. Ind. Min.*, 1960, **42,** July, 605–632) Coils are set around the cable and continuous traces are recorded and analysed for defects.

Nondestructive testing of hardware for solid rocket motors S. M. Joseph (*Nondestr. Test.*, 1960, **18,** Sept.–Oct., 315–318) Various methods used in non-destructive testing of hardware for solid rocket motors are described, including tests used in production and those employed in development programs. Two basic categories are low alloy thin-walled steel pressure vessels heat-treated in the 200000 psi yield strength range, and exit hardware of so-called 'exotic' materials which must withstand the tremendous heat and pressures associated with the exhaust from solid rocket motors. Methods in use on low-alloy chambers and closures include magnetic particle inspection of welds and forgings, and X-ray and liquid penetrant inspection of welds. Ultrasonic inspection of welds is also under active development. On refractory materials, methods include ultrasonic, penetrant, eddy current, and filtered particle inspection.—S.H.-S.

Nondestructive testing. Report of Committee E-7 (*ASTM preprint* 55, 1960, pp.23) This includes tentative methods for liquid penetrant inspection; a detailed procedure for preparation and application of liquid penetrant methods for detecting discontinuities which are open to the surface, such as cracks, seams, lack of bond, etc. A table shows penetration times for ferrous and non-ferrous metals, also for glass and plastics. It also contains a tentative method for ultrasonic contact inspection of weldments.—J.W.J.

Magnetic properties. Report of Committee A-6 (*ASTM Preprint* 4, 1960, pp.53) The report inlcudes revision of standard and reversion to tentative, standard methods for test for permeability of feebly magnetic materials and also standard methods of test for alternating current, magnetic properties of Epstein specimens; standard methods of test for electrical and magnetic properties of magnetic materials; and cup and bend tests for silicon steel sheet and strip.—J.W.J.

Modern magnets and their new uses R. Gaillet (*Mét. Constr. Mécan.*, 1960, **92,** Nov., 853–865) Research into the characteristics of steels and steel alloys suitable for the manufacture of magnets is reviewed and results of tests are reported with comment on recent achievements in production of magnets suitable for scientific and electrotechnical uses.

Metallic materials and ultrasonics J. Klob (*Radex Runds.*, 1960, (6), 323–331) A review of the applications of ultrasonics for metallurgical purposes, i.e. for improving properties during manufacture or subsequent treatment, examining properties, and testing for defects.

Ultrasonic determination of elastic constants of metals at elevated temperatures A. P. Levitt and A. G. Martin (*Nondestr. Test.*, 1960, **18,** Sept.–Oct., 333–336) A simple, rapid and accurate ultrasonic pulse-echo technique for measuring the dynamic elastic contents of metals at elevated temp. and the test system developed for using it are described. The underlying theory of the propagation of ultrasonic waves in polycrystalline solids, including the expressions used to calculate the elastic constants from the measured wave velocities, are presented. Design criteria and methods for meeting them in the development of the test system are discussed. Tensile and shear moduli were determined for the following materials: Super alloys 19–9 DL and Hastelloy C, steels SAE 4140 and 4340, and titanium alloy Ti–155 from room temp. up to 1600°, 2000°, 1500°, and 1200°F respectively. Curves of the variation of those moduli with temp. for each material are presented and discussed. It is believed that data for alloy 19–9 DL, Hastelloy C, and titanium 155 have not been reported previously.—S.H.-S.

Frequency dependent effects in ultrasonic resonance testing R. V. Harris and J. E. Bobbin (*Nondestr. Test.*, 1960, **18,** Sept.–Oct., 327–332) A series of ultrasonic resonance thickness gauges with their uses and the circuitry are described and compared together with a new transistorized Audigauge model which has the additional feature of having a meter indication of the frequency interval calibrated directly in thickness, eliminating the necessity for a separate calculation. Resonance patterns on different classes of metals, alloys, and plastics are described and discussed.

Modulation analysis—a new instrument technique in eddy current testing R. Hochschild (*Nondestr. Test.*, 1960, **18,** Sept.–Oct., 323–326) A technique is described which has resulted in the lowest rate of false flaw indications thus far obtainable, consisting of a series of electronic circuits which suppress instrument response to conditions in the part other than discontinuities.—S.H.-S.

Applied electronics. The evolution of methods of industrial control by X-rays F. Lafay (*Méc. Electr.*, 1960, **44,** Nov., 77–83) A review of the principles and practices of X-ray control, including the detection of defects, operational conditions, the principles of X-ray television and its equipment, image conversion, control of welding, interpretation of results, castings in light alloys and heavy metals, and the pneumatic equipment and road-beds of mechanical transporters.—S.H.-S.

Analysis of radiographic techniques J. A. Holloway, D. Polansky, and E. L. Criscuolo (*Nondestr. Test.*, 1960, **18,** Sept.–Oct., 337–340) An empirical method for determining radiographic techniques by means of a time-latitude curve is introduced. The latitude factor, which is the ratio of the maximum exposure time to the minimum exposure time for a given thickness and sensitivity, is presented for steel in the energy range of 140 KVP to 10 Mev. Latitude factors, as high as 14, which slowly decrease with increasing thickness were found. The effect of scattered radiation on these curves is discussed. A technique and sensitivity curve for steel at 250 KVT is presented. The data illustrates that with a given energy (250 KVCP) extreme thicknesses of flat plate steel (greater than 3in) can be radiographed at a 1% sensitivity level.—S.H.-S.

A technique for ultrasonically testing large forgings with relatively thin wall sections G. E. Ronca (*Nondestr. Test.*, 1960, **18,** May–June, 191–192) The test procedure being used at the Midvale–Heppenstall Plant, Philadelphia, which has successfully resolved reference interfaces not previously satisfactorily detected, is described with results of using shear wave techniques in place of immersion facilities (which are not available at a majority of manufacturing plants.—S.H.-S.

Ultrasonic weld inspection—a status report J. E. Bobbin (*Nondestr. Test.*, 1960, **18,** May–June, 200–202) After a preliminary discussion of ASTM and ASME techniques as a prerequisite for successful weld inspection, the factors surrounding various proposed specifications and reference test plates with a view to attempting to standardize actual procedures used in ultrasonic weld inspection, are presented and described with a reference to the test plate proposed to the International Institute of Welding, which is shown.

Ultrasonic testing of welds R. Hornung (*Sulzer Tech. Rev.*, 1960, **41,** (1), 81–86; from *Brit. Railways Monthly Rev. Tech. Lit.*, 1960, **10,** Feb., 13) The ultrasonic method enables even small flaws, which would not be revealed by any other test, to be detected and accurately located. The knowledge of this fact impels the welder to work with all possible care and thus raises the quality of welds and increases the reliability of welded structures. In addition, the ultrasonic test makes the expensive and laborious pressure testing of high-pressure pipelines unnecessary. Although the theoretical considerations on which the method is based are somewhat complicated, Sulzer Brothers have now developed a system which enables a specially trained worker to carry out the test quickly and without outside assistance both in the workshop and in the field.—R.S.F.C.

A new method of determining the importance of defects by ultrasonics J. Krautkrämer (*Centre Doc. Sid. Cir.*, 1960, (9), 2023–2040; discussion 2040–2041) The first echo from the bottom of a piece of similar material to that being examined is used as a standard of comparison for the attenuated wave which passes through a defect. The reduction in the reflection is proportional to the surface area of the defect. The practical application of this method is described.—A.D.H.

X-Ray examination and weld strength factor O. Eiro (*Lastechniek*, 1960, **26,** Sept., 166–172; from *Welding News*) [In English] The author reviews a series of his own investigations conducted with the object of establishing the relationship between the results of X-ray tests and the mechanical strength of good and indifferently good welds. From the data he obtained from tensile and fatigue tests it is concluded that the fatigue of unworked testpieces is less than that of the base material. Weld defects become more pronounced under dynamic rather than static load, superficial defects are more dangerous than those in the interior of the weld and defects due to slag occlusions are more dangerous than those due to porosity.—F.R.H.

Applications of radiographic stress measurements to metals E. Esenwein and H. Preis (*Schweiz. Arch. Wiss. Techn.*, 1960, **26,** Oct., 401–406) The method of determining the ratio between the stress measured radiographically from the lattice distortion and the actual mechanical stress is discussed.

New facilities for radiographic inspection (*Foundry*, 1960, **88,** Sept., 114–115) Steel casting sections up to 6in or more thick are radiographed at Farrel-Check Steel Co., Sandusky, Ohio, in a new gamma-radiographic inspection room which houses a 5·25-curie source of ^{60}Co. The equipment and precautions for its use are briefly described.

^{137}Cs in γ-ray analysis A. Manole and P. Vezeanu (*Met. Constr. Masini*, 1960, (7), 655–658) The characteristics of ^{137}Cs are a quantum energy of 0·667 MeV with a half-life of 33 years. It has the advantage of being a fission product and therefore easily obtainable with a reactor. The method of use is explained.

The influence of neutron irradiation on the phase transformations in chromium steels B. Weiss-Hollerwöger and R. Mitsche (*Radex Runds.*, 1960, (6), 318–322) The work described investigated the effects of various doses of neutron irradiation on the austenite–martensite transformation at low temp. and the behaviour of the irradiated steel on heat treatment, and was carried out on a steel containing 1·26%C and 5·40%Cr, with 0·01%Ta + Nb. It was found that the martensite point is displaced to higher temp. by irradiation, and that a stabilizing effect is obtained, which reduces the total amount of martensite if high irradiation doses are applied. The results of tempering irradiated specimens were in accordance with the strain-embryo theory of Cohen.

Radiographic contrast in double-film techniques G. M. Corney (*Nondestr. Test.*, 1960, **18,** May–June, 183–184) In the double-film technique for increasing radiographic speed, two films are exposed simultaneously in the same holder and viewed in register. Single- and double-film techniques will give the same radiographic contrast when the total net density on the double film equals the net density in the single film, provided that registration of the double films during viewing is precise and that the densities considered lie

on the straight-line portion of the density-v-exposure curve of the single film. Fine-grained, direct exposure films usually have straight density-v-exposure curves up to a density of at least 1·5.—S. H.-S.

Radioisotopes, their manufacture and use in research and industry E. Schumacher (*Schweiz. Arch. Wiss. Techn.*, 1960, **26**, Oct., 391–395) A brief outline of the production of radioisotopes in nuclear reactors is followed by an enumeration of some of their uses.

Radiotracers reveal engine wear during detergent oil filtration study H. Halliwell (*Trans. SAE*, 1960, **68**, 288–294) The paper described the experimental procedure where radiotracers were used to determine the effect of certain oil variables on wear in marine Diesel engines. The variables considered were filtration, oil detergency level, and abrasive particle size.—A. H. M.

The use of radioactive tracer techniques to determine the effect of operating variables on engine wear B. A. Robbins, P. L. Pinotti, and D. R. Jones (*Trans. SAE*, 1960, **68**, 298–303) Radioactive tracers were used to study the wear effects of engine speed, load, jacket water, fuel temp., and Cr-plated rings in a medium speed diesel engine. The authors conclude that engine speed does not affect the wear rate of cast-iron rings when distillate fuel is used, while with residual fuel wear decreases with increased speed. Also with residual fuel, decreasing engine load produced a marked increase in ring wear.—A. H. M.

Surface tension in iron–manganese and iron–sulphur melts Wang Ching-t'ang, R. A. Karasev, and A. M. Samarin (*Izvest. Akad. Nauk, Otdel. Tekhn. Met. Toplivo*, 1960, (2), 49–51) Mn in liquid iron reduces surface tension from 1865 dynes/cm (for pure iron) to 1372 dynes/cm (for iron with 6·15%Mn). The relation between surface tension and Mn content is linear. S reduces the surface tension of iron to 702 dynes/cm (for a 3·44%S content). Maximum S adsorption is $14{\cdot}6\times10^{-10}$ mol/cm^2 for a concentration of 0·03%S.

Contributions to the data on theoretical metallurgy. XIII. High-temperature heat-content, heat-capacity, and entropy data for the elements and inorganic compounds: iron and its compounds K. K. Kelley (*US Bur. Mines, Bull.* 584, 1960, 93–99) Data are collected from the literature for α-, β-, γ-, δ- and liquid iron; FeO; Fe_2O_3; Fe_3O_4; $Fe_2O_3 \cdot 3H_2O$; FeS; FeS_2; Fe_3C, Fe_2N; Fe_4N; FeSi, $FeAs_2$; FeAsS; $FeBr_2$; $FeCl_2$; $FeCl_3$; FeF_2; FeI_2; $FeAl_2O_4$; $FeCO_3$; $FeCr_2O_4$; $FeCrO_4$; iron cobalt spinel; Fe_2SiO_4; and sulphates and titanates.

Updating high-temperature metallurgy E. S. Jones and L. P. Jahnke (*Met. Prog.*, 1960, **78**, Oct., 131–135) An account of progress in this field since 1958 in the development of high-temp. ferrous and non-ferrous alloys.

The development of refractory sheet metal structures A. V. Levy and S. E. Bramer (*Trans. SAE*, 1960, **68**, 352–365) The authors list the advantages and shortcomings of refractory metals, notably Mo, in applications at temp. up to 2000°F. The mechanical and physical properties of refractory metals are listed and the brittle fracture aspects are discussed.—A. H. M.

The effect of the pig iron structure on its heat conductivity K. L. Sheptunov (*Izvest. Akad. Nauk. Otdel. Tekhn. Met. Toplivo*, 1960, (3), 53–56) These investigations referred to the absolute value and the nature of the change in the thermal conductivity as related to the temp. gradient, and also to the value of the thermal conductivity as related to structure. The temp. coefficients for austenitic irons do not change with changes in the gradient and are higher for ferritic than for austenitic irons.

The effect of low temperatures on the appearance of the fracture and on the plasticity of steels M. P. Braun (*Izvest. Akad. Nauk, Otdel. Teckh., Met. Toplivo*, 1960, (2), 194–109) Very small additions of Ti, V, and W affect the appearance of a brittle fracture. With steel in a ductile condition, W exerts the greatest effect. Mo (0·34%) does not eliminate shortness, although the rate of its appearance at low temp. (−60°) is reduced in the steels containing Mo. The greatest effect on the appearance of a fracture and on the reduction of temp. brittleness is exerted by the complex alloying of steel with (W + Ti).

What are the combined effects of temperature and very high pressure on metals? R. B. Fischer (*J. Met.*, 1960, **12**, Sept., 700–702) Possible effects of these factors on electrical resistance, ductility, hardening, and other mechanical and structural properties of metals are discussed.

Electronographic determination of the heterodiffusion coefficients in the Cu–Ni:Fe–Ni; Cu–Al and Ag–Al systems B. Ya. Pines and I. P. Grebenik (*Kristallografiya*, 1959, **4**, (1), 47–53) The possibility of the electronographic determination of these coefficients is based (as in the case of the X-ray method) on recording the changes in the distribution of the concentrations after an isothermal diffusion anneal. Data are here given for calculating, from these changes, the diffusion coefficients in thin layers of the Cu–Ni and Fe–Ni systems under conditions of 'non-equilibrium' and 'equilibrium'.

An investigation of the diffusion of cobalt and iron along the grain boundaries of cobalt, nickel, and iron S. D. Gertsriken, T. K. Yatsenko, and L. F. Slastnikova (*Voprosy Fiz. Met. Metalloved.*, 1959, (9), 154–161) The coefficients of the grain diffusion of cobalt and iron were much the same for the objects studied. For the auto-diffusion of cobalt along the grain boundaries, the coefficient of grain diffusion is several orders greater than the coefficient of volumetric diffusion and its relationship changes with an increase in temp., decreasing in the temp. interval 500–700° by a factor of almost 20. For the energy of activation of the grain diffusion of cobalt and iron in iron, cobalt, and nickel a linear relationship to the atomic number is obtained.—A.I.P.

A study of the volumetric diffusion of iron in alloys S. D. Gertsriken and M. P. Pryanishnikov (*Voprosy Fiz. Met. Metalloved.*, 1959, (9), 147–153) The diffusion conditions in the α- and γ-regions are very different, not only in pure iron but also in its alloys with small additions of Al. An increase in the compactness of the crystal lattice leads to a sharp reduction in mobility of the atoms and significantly increases the energy of activation of diffusion (15 refs).—A.I.P.

Concerning the question of the parameters of the auto-diffusion of iron in the δ-region of iron alloys with a small amount of aluminium D. D. Gertsriken and M. P. Pryamishikov (*Voprosy Fiz. Met. Metalloved.*, 1959, (10), 68–73) The auto-diffusion parameters are studied in the case of iron and of its alloys with 0·27–0·39%Al at 1320–1480°C.—A.I.P.

Self-diffusion of iron and sulphur in ferrous sulphide R. H. Condit and C. Birchenall (*AFOSR–TN–60–245; PB* 147772, 1960, March, pp.126; from *US Res. Rept.*, 1960, **34**, Sept. 16, 325) Measurements of the self-diffusion of iron and sulphur in FeS single crystals are reported as a function of temp., deviation from stoichiometric composition, and crystallographic direction. Iron self-diffusion is primarily by a vacancy mechanism, the vacancies being provided by the iron deficit plus a small intrinsic disorder. Details of the diffusion mechanism are discussed, and it is concluded that direct jumps between normal sites aligned along the c-axis are favoured over jumps from normal to interstitial sites which might then be followed by later jumps into new normal sites. However, the Bardeen-Herring correlation factor appears to operate in such a way that the rate limiting step for diffusion in both crystallographic directions is the jump from normal to interstitial sites.—C. F. C.

Effect of arsenic on the structure and properties of St.3sp killed steel heavy rolled products A. V. Demakova, L. P. Tarasova, and Z. I. Baranova (*Stal'*, 1960, (12), 1127–1130) Extensive studies are reported, concluding that up to 0·26%As has no effect on mechanical properties and impact strength. Certain inhomogeneities of C, As, P, and S distribution through the ingot were found with consequent changes in properties between top and bottom. A banded ferrite structure is associated with As content.

Cobalt in special steels (*Mét. Constr. Mécan.*, 1960, **92**, Nov., 901–912) A comprehensive review of the history of the use of Co, the Fe–Co reaction, the effect of Co on forgeability and hot mechanical strength of steels, the uses of alloys for high temp. and alloys for permanent magnets. A series of other special uses for Co including radio valve filaments and glass for emission lamps, are summarized.—S. H.-S.

The effect of small amounts of vanadium on the properties of structural steels M. I. Gol'dshtein and S. G. Guterman (*Stal'*, 1960, (12), 1130–1134) Strength is increased, probably by a dispersion-hardening process, with even 0·01–0·03%V. Hardness and tensile strength increase and ductility and impact strength are reduced. Tempering at higher temperatures is necessary.

Residual elements in steelmaking F. C. Langenberg and J. F. Johnson jun. (*Met. Prog.*, 1960, **78**, Sept., 69–76) The sources of a number of minor constituents and their effects on steel properties are reviewed.

Silicon irons up to date W. Morrill (*Met. Prog.*, 1960, **78**, Sept., 84–87) Developments and research in grain-oriented, anisotropic Si iron are reviewed.

Nickel as a hardener of iron F. B. Foley (*Met. Prog.*, 1960, **78**, Sept., 128, 130) A letter. Evidence is given to indicate that it is not Ni in solid solution as such which causes increased hardness in iron, but the fact that it produces a lowering of the Ar_3 temp.

Iron–chromium, iron–chromium–nickel, and related alloys. Report of Committee A–10 preprint (*AST'M Preprint* 5, 1960, pp.4) Contains revision of standards and reversion to tentative, for corrosion-resisting steels; steel bars, annealed and cold finished, and castings. It includes also reports of sub-committees on specifications for wrought products, castings, tubular products, high-temp. super-strength alloys, and nuclear reactor structural materials.—J. W. J.

Non-nuclear uses of uranium S. L. Gertsman (*Canad. Dept. Mines Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 54–55) 0·4%C steel containing U was tested; brittleness appears at 0·5%U. The carbides formed in U-bearing steels are being examined and its use as a deoxidizer has been tested in preliminary trials.

Boron in steel R. A. Grange and J. B. Mitchell (*Met. Prog.*, 1960, **78**, Oct., 264, 266) Digest of 'On the hardenability effect of boron in steel' *ASM preprint* No.188, 1960. The mechanism of the hardening effect of B in steel was investigated by studying the influence of austenitizing treatment on the B constituent.

Phosphorus in stainless steel R. W. Guard, G. R. Rundell, and R. J. Raudebaugh (*Met. Prog.*, 1960, **78**, Oct., 244, 246) Digest of 'The effect of phosphorus on the elevated-temperature strength and weldability of some low-carbon austenitic stainless steels', *ASM Preprint no.* 194, 1960. Measurements reported on high-temp. properties and hot ductility of several small heats indicate that P will markedly improve high temp. strength of both type 304 and type 316 stainless steels, and weldability is not adversely affected if C content is kept below 0·03% and Ni is at the lower end of the specification. Charpy impact tests show that transformation of retained ferrite to sigma phase gives a drop in impact strength which is not serious.

The effects of arsenic, phosphorus and carbon on the properties of steel K. F. Starodubov and V. V. Kalnykov (*Stal'*, 1960, (11), 1034–1037) Addition of up to 0·75%As to a 0·15%C steel and low (0·015%)P does not affect strength or ductility. With higher C reduction in area is lowered. Impact strength is not changed by up to 0·13%As and only slightly reduced by 0·3%. Increase of P to 0·06% (without As) slightly increases hardness, strength, and yield-point without reduction in impact strength, but with higher C (0·45 and 0·75% tested) brittleness increases. As + P produce embrittlement especially with high carbon.

The effect of alloying on the properties of hypoeutectoid tool steel Yu. A. Geller and E. A Lebedeva (*Metalloved. Term. Obra. Met.*, 1960, (3), 31–40) The alloying of tool steels of different compositions differs greatly in the distribution of carbides, in hardenability and in the technological properties obtained. Steels without sufficient susceptibility to quenching are

not uniformly hardened. A reduction in the hardness from 63 to 61 RC increases plastic deformation. The different tool steels are considered from this point of view, especially their structures and the properties of deformed annealed steels, the tendency to the formation of carbide networks, the structure and properties of quenched steels, the strength, the susceptibility of steels to quenching, hardenability, the properties of tempered steels, etc.

Investigation of steels with and without vanadium for forgings G. Delbart, M. Jaspart, A. Clerc, and A. Constant (*Rev. Mét.*, 1960, **57,** Oct., 885–909) The effects of additions of 0·03–0·8% and 0·29%V on the mechanical properties of C, Cr–Mo, and Cr–Ni–Mo steel bar specimens are examined. It is shown that the improvement in properties resulting from the V additions enables quenching to be replaced in some cases by normalizing and increased tempering temps.

New nickel materials H. A. Hocking (*Radex Rundschau*, 1960, (6), 353–364) The improved supply position for Ni resulting from the opening of the Manitoba mine of International Nickel Co. of Canada, and its consequences are reviewed, and the properties of several Ni alloys are described, including a 9%Ni steel having good low-temp. and case-hardening properties.

High alloy stainless steels and alloys J. Bourrat (*Mét. Constr. Mécan.*, 1960, **92,** Nov., 867–878) A review of 18/10 Mo stainless steels, including high alloy nickel alloys Hastalloys B, C. F. and D.—S.H.-S.

Standard stainless steels. Latest developments and uses L. Guitton (*Mét. Constr. Mécan.*, 1960, **92,** Nov., 881–898) A review of the production, treatment, testing, and uses of 17%Cr and 18/10 Mo steels, their electrolytic polishing qualities, and resistance to corrosion.

Steels and refractory alloys. Principles governing their use R. Neyret (*Chim. et Ind.*, 1960, **84,** Dec., 879–890; also *Mét. Constr. Mécan.*, 1960, **92,** Nov., 931–953) The most important characteristics of steels and refractory alloys are their resistance to oxidation at high temp. and their resistance to creep. These steels and alloys are generally on an Fe, Cr, and Ni base, and sometimes Co. The author examines the composition and physical properties of ferritic steels, austeno-ferritic steels, and austenitic steels at room temp. as well as at 700–1000°C. He then studies their behaviour in different hot atmospheres, and the influence of certain elements (S, SO_2, and V_2O_5) and gives a survey of some Co refractory alloys.

Inoculating a forging iron of high chromium content M. A. Krishtal and E. G. Titenskii (*Lit. Proizv.*, 1960, (9), 33–35) The investigation refers to tests for neutralizing the effects of the Cr by additions of Sb and B and also by compound inoculating mixtures consisting of B and Bi, and B and Sb. B is introduced in the form of Fe–Si–boride and of Fe–B, in concentrations of 0·003–0·10% on the weight of iron. Sb and Bi are used in metallic form. The resulting mechanical properties are tabulated.

Microstructure and notes on carbon steels to B.S.3100:1957:502 Grade A J. Turton and B. H. C. Waters (*Brit. Found.*, 1960, **53,** (9), Sept., 407–410) Mechanical properties and microstructures which may be obtained from cast steels made to BS.3100:1957:592 Grade A are compared with the average values of the specification.—A.D.H.

High carbon steels for lathe components replacing cemented steels E. M. Morozova and A. P. Skuzovatova (*Stanki Inst.*, 1960, (7), 27–29) Tests have shown that the resistance of chromium ShKh15 steel is higher than that of the cemented layer of 20Kh steel by a factor of approximately 2, and that the dynamic strength of U8A, U10A, and ShKh15 steels is higher by a factor of 3 as compared with that of the layer of cemented 20Kh steel. Suggestions are given as to which components could best be made out of these high carbon steels.

High-strength martensitic steels for elevated-temperature use A. Kasak, V. K. Chandhok, and E. J. Dulis (*ASM preprint* 220, 1960, 621–636) Steels with 0·38%C, 2%Cr, 1%V, 5·8%Mo, and 5%Co with some variations in composition were studied and their tensile and creep strengths at room temp. and 1100°F determined. Carbide formation and coalescence at the grain boundaries correlated with creep strength and type of fracture.

Specification for Kh15N35VMT heat-resisting steel (EI 692) (*Metallov. Term. Obra. Met.*, 1960, (1), 61–64) A specification issued by TsNIIChM. The material is a low-C austenitic steel of composition 0·18%C, 0·6%Si, 1%Mn, 14–16%Cr, 32–38%Ni, 2·3–3%Mo, 2·3–3%W, 1·1–1·5%Ti, and not more than 0·02%S and P. It is delivered as rolled sections and forgings and is intended for long service at 600–700°. It is recommended for turbine blades for use at 650–700° for periods of up to 100000 h and for reinforcing components working at temp. of 650–680° for periods of up to 10000 h.

Stainless steel looks to the future American Iron and Steel Institute (*Metalw. Prod.*, 1960, **104,** June 8, 57–60) The development of new stainless steel alloys, new mill techniques, and new ways of working are briefly reviewed and prospects in the aeronautical and nuclear fields discussed with much factual production data.—S.H.-S.

Alloy research: Naval rotor forgings S. L. Gertsman (*Canad. Dept. Mines Techn. Surv., Phys. Met. Sec., Res. Special Proj. Rep.*, 1960, Jan. 15, 1) New steels for forgings and work at 565°C in steam have been produced by the Dominion Steel and Coal Corp. Ltd, and Cr–Mo–V steel was forged, dehydrogenized and tested.

Development of ultra-high-strength steels and tool steels at Atlas Steels Ltd (*Canad. Dept. Mines Tech. Surv., Phys. Met. Sec., Res. Spec. Project Rep.*, 1960, Jan. 15, 2) Studies of 5%Cr steels are briefly reported with the effects of varying C, V, Mo, Si, Mn, and B, and a steel with an endurance limit of 136000 psi has been developed.

Microstructures and notes on steels made to B.S.1617:1957 Grade B W. J. Jackson and E. J. Ridal (*Brit. Found.*, 1960, **53,** (8), Aug., 376–379) Magnetic and mechanical properties of annealed and normalized steels containing 0·19–0·34%C are presented with typical microstructures.—A.D.H.

Advances in stainless steels R. E. Paret (*Met. Prog.*, 1960, **78,** Oct., 81–83) (From *AISI* Committee of Stainless Steel Producers) Topics discussed include: high-strength hardenable austenitic alloys, martensitic alloys for bearings, austenitic steel, steel with over 0·3%P to give greater rupture strength at elevated temps., and steels for low-temp. use.

How to get more from modern steels (*Met. Prog.*, 1960, **78,** Oct., 71–80) [From a questionnaire] The properties of some high-strength steels are outlined, and the strength-to-cost ratio of some constructional steels tabulated. Various applications of high-strength steels are enumerated, and the possibilities of various types discussed. These include Co-treated steels, new H-steels, leaded steel, new Ni steels, galvanized, and vinyl-coated steels.

Development of high-temperature iron-base alloys A. Kasak, V. K. Chandhok, and E. J. Dulis (*WADC Techn. Rep.*, 59–353; *PB* 161337, 1959, Oct., pp.62) An investigation is reported on the development of steels combining very high strengths at room temp. and at ~1200°F. Highest strengths were attained with compositions of 0·35–0·40%C, 7–9%Cr, 0·5–1·0%V, 5–7%Mo, 5–8%Co, up to 1%Ti, up to 1%Ta+Nb, up to 1·5%W, and up to 0·01%B. One steel cited had a tensile strength of 310000 psi at room temp., and 201000 psi at 1100°F, with a 100-h creep-rupture strength at the latter temp. of 98000 psi. Excellent strengths were also obtained at 1200°F.

The task of improving the quality of electrotechnical steels and alloys A. M. Samarin (*Izvest. Akad. Nauk, Otdel. Tekhn., Met. Toplivo*, 1960, (3), 117–120) A review of the efforts made at various works with Al alloys, structural steels, and semi-conductor materials to economize in scarce metals for alloying.

Hydrogen in cold worked steel J. E. Werner and H. M. Davis (*Met. Prog.*, 1960, **78,** Oct., 174, 176) Digest of 'On the mechanism of occlusion of hydrogen by cold-worked hypoeutectoid iron–carbon alloys' (*ASM preprint No.*237, 1960). In addition to an endothermic mechanism, it is shown that occlusion also occurs by an exothermic process, apparently by sorption on internal surfaces. Occlusive capacity and nature of the occlusions were investigated by equilibration of low-metalloid steels with O_2-free dried H_2 between 200 and 400–550°C.

The occlusion of hydrogen by annealed hypereutectoid iron–carbon alloys M. Kotyk and H. M. Davis (*ASM preprint* 222, 1960, 653–661; also digest in *Met. Prog.*, 1960, **78,** Oct., 176, 180, 192) Carbon steels with 0·015, 0·17, 0·23, 0·33, and 0·45%C and with various forms of carbide were equilibrated with H_2 at 40–550°C and amounts and conditions of occlusion were determined with thermal and enthalpy data.

Cooperative research in Britain's steel industry D. Hunt (*J. Met.*, 1960, **12,** June, 476–479) The story of BISRA, the first of a series of articles describing major metallurgical research organizations here and abroad. The article summarizes: organization, divisions and departments, laboratories, research philosophy, some achievements, new instruments and apparatus, application of research, and gives an appraisal of BISRA.—S.H.-S.

Max Planck Institutes for metallurgical research 1—the Max-Planck-Institüt für Eisenforschung, Düsseldorf, Germany W. Wepner (*J. Met.*, 1960, **12,** Sept., 692, 693) An outline of the range of work undertaken.

Max Planck Institutes for metallurgical research 2—The Max-Planck-Institüt für Metallforschung, Stuttgart, Germany W. Koster (*J. Met.*, 1960, **12,** Sept., 694–695) A brief outline of the development of the institute and its programmes.

METALLOGRAPHY

Transmission electron microscopy of metals: α-iron S. L. Gertsman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 42–43) Effects of small amounts of deformation were observed.

Microscopical investigation of spheroidal graphite by new methods J. Blaha, F. Grasenick, H. Horn, and E. Jakopic (*Radex Rundsch.*, 1960, (6), 429–446) A description of methods of isolation, thin sections, and reproduction is given of a method suitable for examination of spheroidal graphite with the electron microscope. Photographs are reproduced, including X-ray stereograms.

Observation and recording of variable processes in the emission electron microscope H. Düker (*Radex Rundsch.*, 1960, (6), 406–520) Applications and illustrations of the use of emission electron microscopy are given, and the construction and application of a vacuum line camera for recording changeable processes in conjunction with the microscope are described. An example given is the $\alpha \rightarrow \gamma$ transformation of 0·45%C steel.

The application of the electrolytic pad and nitrocellulose replicas to non-destructive metallography of ferrous materials P. A. Jacquet (*Centre Doc. Sid. Sirc.*, 1960, (7–8), 1737–1761; discussion 1761–1764) Electrolytic polishing, when electrolyte is contained in a porous pad held on the surface, can be used to prepare the surface of large components for metallographic examination. Nitrocellulose replicas are used for optical and electron microscopy of metal surfaces. Examples of the techniques are given.

The microstructure of low-carbon 3·25% silicon steel W. C. Leslie, R. L. Rickett, C. P. Stroble, and G. Konoval (*ASM preprint* 226, 1960, 715–734) Carbon content, even within the very narrow limits encountered, and temp. of heating have profound effects. Fe_3C and one, or possibly two, unidentified metastable carbides were present, precipitated at 595°C and below. Speckled aggregates, one within the carbide and the other within the austenite appear in trace amounts.

Separation and study of carbides in steels C. Bondy (*Bull. Cercle Etudes Mét.*, 1960, **8,** June, 37–94) Methods of isolating carbides in steels are reviewed, and electrolytic procedures are mentioned. Various methods of study and analysis of carbides are described, and physical, crystallographic, and thermodynamic data are reported. Results of carbide reactions in steels are briefly described.

Contribution to the isolation and analysis of oxide inclusions in steel S. Meyer and O. G.

Koch (*Arch. Eisenh.*, 1960, **31**, Nov., 651–657) The possibilities of electrolytic dissolution without the use of protective atmospheres is examined, the method recommended involving the use of reducing agents. Techniques of sampling, and of the micro-chemical and spectrographic analysis of inclusions are discussed (28 refs).

Study of segregation. Non-metallic inclusions in the centrifugal castings and investigation on the causes of cracks M. Ochiai and A. Hyono (*Imono*, 1960, **32**, July, 502–514) A series of tests is described on the causes of cracks in centrifugal cast steel of complicated design, and results are presented, with observations on the segregation of C, Si, and Mn from the centre of castings to the outside; of P and Cu practically the same in the inside and at the outside of castings; and of S segregating on the outside.—S.H.-S.

Precipitation of phosphorus from alpha iron and its effect on plastic deformation E. Hornbogen (*ASM preprint No.*217, 1960, 569–589) With >1%P plates and rods of a phosphide phase, apparently face-centred orthorhombic, are produced which transform to Fe_3P on ageing. Hardening occurs at 350–700°C and twinning is inhibited. Effects on slip and shear are discussed.

Revealing lead inclusions in leaded steels G. M. Chalfant (*Met. Prog.*, 1960, **78**, Sept., 77–79) A metallographic technique is described for revealing and identifying Pb inclusions in leaded C, alloy, and resulphurized steels. Grinding, polishing, and etching procedures are described; final polishing is done on a cloth containing the etching reagent, a solution of γ-Al_2O_3 at pH 7, which is finally sprayed on the specimen before drying.

The carbide phase in carbon steels during electric tempering V. N. Gridnev and Y.I. Trefilov (*Voprosy Fiz.Met. Metalloved., Kiev*, 1959, (10), 86–93) It has been found that a slowing down of the agglomeration processes takes place, which ensures that high dispersion of the carbides is maintained. This, together with the previously-studied structural state of the ferrite, ensures that the steel is of high strength and durability.—A.I.P.

The electron-microscopical investigation of the carbide phase during the tempering and the electric tempering of carbon steels V. N. Gridnev, Yu. N. Petrov, and V. I. Trefilov (*Voprosy Fiz. Met. Metalloved*, 1959, (10), 94–103) Results are presented in some detail of experiments on types U12A and 50 steels (chemical compositions given) with tempering at various temp. (16 refs).—A.I.P.

The influence of aluminium nitride on the determination of oxide inclusions in fully-killed Thomas steels E. Piper, H. Hagedorn, and M. Fröhlich (*Arch. Eisenh.*, 1960, **31**, Oct., 577–585, discussion 582–585) Considerable deviations were found in the residue analysis in basic Bessemer steels with 0·1–0·4%Al compared with the vacuum fusion results. This was attributed to the occurrence of AlN needles and prisms.

Occurrence of aluminium nitride in fully-killed Thomas steels E. Zimmermann (*Arch. Eisenh.*, 1960, **31**, Oct., 587–594) Up to 85% of the total N_2 content was found in the anodic isolate of killed basic Bessemer steels. The variation of chemical resistance of the isolated Al nitrides was attributed to grain size. The relationship between some of the physical properties of the steel and the structure of the nitride is discussed (23 refs).

Regarding the ordering in iron nitride phases G. G. Dvoryankina and Z. G. Pinsker (*Kristallografiya*, 1960, **5**, (2), 253–256) The hexagonal iron nitride structure with a spacing of $a = 2{\cdot}765$ Å and $c = 4{\cdot}41$ Å was investigated, in thin layers, when it was found that partial ordering of the N atoms takes place. The structure can be described by the spatial D^3_{3d} grouping. In the most compact hexagonal arrangement of iron atoms, the N atoms arrange themselves in octahedral planes occupying statistically all positions, but in one layer (000) with twice the probability of the other ($00\frac{1}{2}$).

The distribution of calcium in cast steel N. S. Kreshchanovskii (*Lit. Proizv.*, 1960, (8), 31–33) The findings of the investigations here reported show that metallic Ca exerts a strong influence on grain refinement in carbon and austenitic Cr–Ni steels. In carbon steels, Ca is present in the form of non-metallic inclusions (sulphides, oxides, nitrides, etc.) and, in insignificant amounts, in the solid solution, although this latter point is not definitely established since its presence there may be due to the dissolution in the electrolyte of some of the unstable compounds of carbon steels (Ca_2Pb, Ca_2Pb_2, $CaCu_5$, etc.). In Cr steels, Ca is present as non-metallic inclusions and in compounds of an intermetallic character.

The influence of oxides on the crystallization of iron and of certain of its alloys D. E. Ovsienko and V. P. Kostyuchenko (*Voprosy Fiz. Met. Metalloved*, 1959, (10), 130–143) Results of the investigations showed that iron oxides belong to the class of naturally occurring constituents which under certain conditions, can completely determine the kinetics of crystallization both of iron and of some of its alloys (17 refs).—A.I.P.

Grains within grains R. C. Gifkins (*Trans. Austral. Inst. Met.*, 1954 and 1955, **7–8**, 127–136) A discussion of substructures found in metallic crystals such as those found in creep, polygonization, and recrystallization structures, mosaic structures found in annealed metals or revealed by electron microscopy. Classifications based on method of formation intended to clear up ambiguities of description and nomenclature are given (81 refs).

The change in the crystalline fine structure of the residual austenite in the tempering of high-speed steel P. M. Yushkevich (*Metalloved. Term. Obra. Met.*, 1960, (2), 14–20) At tempering heats between 200 and 600° the increased lattice parameters (increased without diffusion) of the residual austenite are reduced by diffusion. Because of the compression from all sides of the residual austenite the maximum displacement of the atoms of iron in the equilibrium positions amounts to 0·008 Å. The reduction in hardness in the first stages of tempering is accompanied by an increase without diffusion in the lattice parameters of the residual austenite, by a fragmentation of the mosaic blocks and by a decrease in the distortions of the IInd order.

Effect of rolling procedure on the kinetics of recrystallization of cold-rolled iron J. T. Michalak and W. R. Hibbard jun. (*ASM preprint* 202, 1960, 331–348) Studies were made of the effects of the following variables on the recrystallization of cold-rolled common iron: (a) Straight-rolling, (b) cross-rolling, (c) time of recrystallization, (d) temp. of recrystallization, (e) apparent nucleation frequency, (f) growth rate, and (g) preferred orientation. The results indicate significant effects, but no new leads regarding the mechanism of recrystallization, control of textures, or the formation of new textures were discovered.—E.S.F.C.

Investigation of the kinetics of recrystallization of pure iron after rapid heating by an electric current V. I. Ivanov and K. A. Osipov (*Izvest. Akad. Nauk, Otdel. Tekhn., Met. Toplivo*, 1960, (2), 87–92) Investigations have shown that the kinetics of recrystallization of pure iron (99·76%) under isothermal conditions remain practically unchanged between 520–600° for an increase in the rate of heating from 0·5–500°/sec. On increasing the annealing temp. above 600° at a rate of heating of 500°/sec. the moment of the initial recrystallization is advanced by fractions of a sec at the same time as the activation energy in the initial stage of recrystallization is reduced from 57·25 to 26·9 kcal/g atom. It has been demonstrated experimentally that the principal reason for this change of recrystallization kinetics with rapid electrical heating is the combination of the processes of recovery and of recrystallization with time and temp.

The effect of high heating rates on the structure and properties of steel V. N. Gridnev (*Voprosy Fiz. Met. Metalloved.*, 1959, (9), 54–67) Results are given of recent experiments carried out at the Kiev Polytechnic Institute and the Institute of Metal Physics of the Ukrainian Academy of Sciences into transformations at high heating rates. Temp., elongation, reduction in tension, and other parameters were recorded simultaneously.

The transformation in annealed Armco iron at high rates of heating V. N. Svechnikov and Yu. A. Kocherzhinskii (*Voprosy Fiz. Met. Metalloved.*, 1959, (10), 182–185) Thermal, dilatometric, and heat-capacity methods have shown the complete progress of the $\alpha \rightarrow \gamma$ transformation at the transformation temp. in annealed Armco iron, heated at a rate of at least 900°/sec.—A.I.P.

Peculiarities of transformations during the rapid recrystallization of steel F. K. L'vov (*Nauchn. Dokl. Vyssh. Shkoly. Met.*, 1959, (1), 203–205) Rimming steel with 0·08%C cold-reduced 60% was electrically heated and sprayed with water. The possibility of heat-treating strip or wire by heating very rapidly to a high temp. and cooling rapidly is suggested, using induction heating.

An investigation of the solid-state transformation of Co–Cr–Fe alloys V. N. Svechnikov, A. Ts. Spektor, and E. E. Maistrenko (*Voprosy Fiz. Met. Metalloved.*, 1959, (10), 168–181) The melting process employed and the chemical compositions of all the alloys investigated are given. The method of investigation of the phase boundaries and the results of the investigation of the ternary system Co–Cr–Fe are presented at ordinary temp., 600° and 1000°C.—A.I.P.

Phase transformation in carbon-free iron alloys during electro-heating V. N. Gridnev and V. T. Cherepin (*Voprosy Fiz. Met. Metalloved.*, 1959, (9), 98–104) The investigation was carried out on the following alloys: Fe–Si, Fe–Cr, Fe–Cu, Fe–W, Fe–Ti, Fe–Ni. The alloys were studied in the annealed and the quenched state. Annealing was carried out in H_2 at a temp. of 1100° for 4 h. Quenching was from 1100°C in 10%NaOH. Results are presented.—A.I.P.

The precipitation of carbon in iron O. Krisement (*Arch. Eisenh.*, 1960, **31**, Nov., 677–686) Experimental results on the precipitation of C in α- and γ-iron are compared with theoretical findings, the influence of plastic deformation is examined, and the annealing of martensite investigated (30 refs).

The precipitation of carbon from alpha-iron. I. Electron microscopical study R. H. Doremus and E. F. Koch (*Trans. Met. Soc. AIME*, 1960, **218**, Aug., 591–596) The first carbide phase that precipitates at 120°C from α-iron containing about 0·02 wt-%C was studied with the electron microscope. In both strained and unstrained material the carbide particles appeared to form on the dislocations in the iron, in agreement with the results of the kinetic study in Part II. The structure of the carbide was tentatively defined as an expanded α-iron lattice (body-centred tetragonal) with about 0·7 wt-%C. This phase appeared to be metastable and apparently transformed into cementite or ϵ-carbide when the iron was overaged (19 refs). **II. Kinetics** R. H. Doremus (596–605) From measurements of carbide precipitation rates in α-iron it was concluded that the carbides nucleated on dislocations in both strained and unstrained samples, except for the latter at lower temp. and higher carbon concentrations, where there were more nuclei than could form on the dislocations. The equation of Cottrell and Bilby for the segregation of atoms to dislocations was found to be inapplicable to this system. No satisfactory theory for the growth process is available (33 refs).—S.H.-S.

Precipitation of carbon from solution in α-iron S. L. Gertsman (*Canad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 47–48) Electron microscopy of thin foil has been continued. The appearances produced are described. **The effect of the distribution and composition of carbides on the secondary hardening and high temperature properties of alloy steel** (49–50) Creep tests on foils *in vacuo* are assessed and examined by the electron microscope. **Isolation of carbide particles and non-metallic inclusions in steels** (50–51) An ultra-high-strength Cr–Mo–V secondary hardening steel was examined and the composition and number of inclusions determined. Effects of tempering were investigated. A theory for the formation of maximum precipitate at a temp. below that corresponding to peak hardness is advanced.

Sulphur segregation at α-iron grain boundaries. J. N. G. Ainslie, R. E. Hoffman, and A. U. Seybolt (*Acta Met.*, 1960, **8**, Aug., 523–527) Sulphur can segregate in the neighbourhood of α-iron grain boundaries, apparently as an equilibrium solute, in directly observable and measurable amounts. Although polycrystal specimens exhibiting this grain boundary segregation contained 50–100% more sulphur than did single crystal control specimens, the amount of apparent grain boundary adsorption exceeds, by a factor of at least 30, that permitted by the Gibbs adsorption isotherm. The extra sulphur contained in the polycrystals would, if concentrated at the grain boundaries, be sufficient to coat the boundaries with 100–150 atom thicknesses of pure sulphur. The grain boundary excess of sulphur cannot be explained by preferential grain boundary diffusion and concomitantly incomplete bulk diffusion, nor yet in terms of preferential grain boundary precipitation of sulphides. II N. G. Ainslie, V. A. Phillips, and D. Turnbull (528–538) In this part an attempt is made to find an explanation for the unusual segregation phenomenon presented in the preceding paper. High purity α-iron polycrystals containing sulphur as a result of exposure to H_2S tend to exhibit a dense dislocation network structure associated in general with the grain boundaries. The networks are extensive, in some cases up to 15 μ on either side of the boundaries. The dislocation densities of the networks are comparable with those of fully cold-worked metals. In contrast, pure unsulphurized iron does not exhibit such networks. The networks probably form by a regenerative climb process: sulphur rushes in along the grain boundaries and then diffuses laterally into the bodies of the grains, establishing a Kirkendall diffusion zone and a concomitant vacancy under-saturation, which provides the energy for the climb and multiplication of dislocations. The apparent greater solubility of sulphur in polycrystals than in single crystals of iron, reported in the preceding paper, is now qualitatively explained in terms of sulphur adsorption at the dislocation networks.—S. H.-S.

The sulphide inclusions in steels with titanium additions Yu. T. Lukashevich-Duvanova and V. A. Urazova (*Izvestia Akad. Nauk, Otdel. Tekhn., Met. Toplivo*, 1960, (2), 42–48) It has been established that the nature and the composition of Ti sulphide inclusions change with the concentrations of carbon and oxygen, and that there are no simple Ti sulphide inclusions in the low carbon steels, but diffusion-inclusions of carbide-sulphides of Ti in the form of $TiC+Ti_2S_2$ or Ti oxysulphides of the formula $TiO_2+Ti_2S_2$. Their proportions increase with an increase in the Ti content in the metal. The carbide–sulphides form when Ti is added to the previously deoxidized metal.

Precipitation processes in copper-rich copper–iron alloys A. Boltax (*NMI*–1210, 1959, Aug., pp.44; from *Nucl. Sci. Abs.*, 1959, **13**, Dec. 31, 2998) A technique is described for studying the precipitation processes in Cu–Fe alloys by means of electrical resistivity and magnetic measurements.

Nucleation and growth of pearlite A. Hultgren and H. Öhlin (*Jernkont. Ann.*, 1960, **144**, (5), 356–391) [In English] Cementite and ferrite were examined under polarized light, and the relative lattice orientation of different units was determined. Pearlite was found to be nucleated in a hypoeutectoid steel by grain boundary ferrite, and in a hypereutectoid steel by grain boundary cementite. Mechanisms of nucleation and growth are discussed (22 refs).

Rates of growth of cementite in hypereutectoid steels R. W. Heckel and H. W. Paxton (*Trans. Met. Soc. AIME*, 1960, **218**, 799–806) Metallographic measurements of rates of thickening of grain boundary films and of Widmanstätten cementite were compared with a model based on diffusion controlled growth and with rates predicted from the Zener-Hillert expression respectively. Grain boundary films grew more quickly than would be expected on the basis of diffusion-controlled growth, and the rate was greater for a pure Fe–C alloy than for plain C steel of similar C content. The Zener-Hillert expression for edgewise growth of Widmanstätten plates gives rates several orders of magnitude greater than those observed experimentally in plain C steels. The results are discussed (27 refs).

Growth behaviour of cube-oriented secondary recrystallization nuclei in high-purity silicon iron J. L. Walter and C. G. Dunn (*Trans. Met. Soc. AIME*, 1960, **218**, Oct., 914–922) The nature of the slow growth or nucleation stage of secondary recrystallization to the cube texture in sheets of high-purity 3%SiFe is investigated (19 refs).

Changes of structure and properties of cast iron in the solid state W. Jellinghaus (*Stahl Eisen*, 1960, **80**, Nov. 10, 1695–1700) The effect of Si in cast iron was studied with respect to the rate of the austenite decomposition and to the transition stages between metastable and stable structures. The absorption of Si by cementite was included in these studies. The results are presented in graphs, tables, and micrographs. An extensive bibliography is appended.—T. G.

Crystallographic relationships between the γ-phase and the α-phase obtained by the application of cold working to unstable austenite P. Bastien and R. Margerand (*Rev. Mét. Mém. Sci.*, 1960, **57**, Oct., 778–786) After a review of earlier results, the orientation relationship is given between the austenite and the α-phase obtained by wire-drawing. The results can be explained by making use of the 'Bain model' and 'dislocation transformation' (13 refs).

Behaviour of carbide and nitride in the transformation of carbon steels (*Denki-Seiko*, 1960, **31**, March, 69–73) [In Japanese].—K. E. J.

γ ⇌α-Phase transformation during ageing of 18–8-type steel first deformed at minus temperatures A. N. Chukhleb and V. P. Martynov (*Fiz. Met. Metallov.*, 1960, **10**, (2), 240–244) It has been established that secondary hardening during ageing occurs between 225° and 425°. This second hardening is considered to be due to additional formation of the magnetic phase. The time effect during holding while ageing on the variation of the properties of this steel has also been investigated. Hardening due to plastic deformation at sub-zero temp. (forging, rolling, drawing) may be increased further by ageing 1 h at 400°.

Identification of χ- and σ-phases in stainless steel with the electron probe microanalyser L. S. Birks, J. M. Siomkajlo, and P. K. Koh (*Trans. Met. Soc. AIME*, 1960, **218**, Oct., 806–809) It is shown that the estimated Cr–Mo ratio can be used to identify the two phases with better than 95% confidence *in situ*, even when the precipitate size is < the electron beam size.

The effect of small chromium contents on the isothermal transformation rates of steel wire G. G. Brown and H. C. Coe (*J. Austral. Inst. Met.*, 1960, **5**, Aug., 118–122) The authors have investigated the effect of residual amounts of Cr on the isothermal transformation rates of 0·7%C steel wire. The effect is shown to depend on the temp. of transformation and on the austenitizing treatment employed.—G. F.

Effect of chromium, molybdenum, tungsten, and manganese on the transformation behaviour of steels containing 1% carbon K. Bungardt and O. Mülders (*Stahl Eisen*, 1960, **80**, Oct. 27, 1603–1618) The effect of Cr, Mo, W, and Mn on the transformation kinetics in the pearlite and bainite stage was studied on steels containing C and Cr 1% each, after quenching from the field of homogeneous austenite. The results of the studies are reported in detail (50 refs).—T. G.

Irradiation-induced phase transformations in metals and alloys R. Smith (*J. Austral. Inst. Met.*, 1960, **5**, Aug., 163–172) The author describes the damage considered to be produced by neutron bombardment in a metal, and discusses the observed effects of irradiation on order–disorder, precipitation, phase-reversal, and martensitic reactions, in relation to the theory of radiation damage.—G. F.

Investigation of the eutectoid transformation in austenitic steels M. I. Zakharova and Wang Hua-fou (*Fiz. Met. Metallov.*, 1960, **10**, (1), 70–74) The investigation by X-ray analysis of the eutectoid transformation in mono- and polycrystals in a steel with 12%Mn+1·2%C and in one with 1·77%Mn+2%C is here discussed. Results show that even at the same tempering heat, the order of the segregations of the α-phase and of the carbides is different in single and in the polycrystals. In the polycrystals, X-ray analysis reveals an initial segregation of carbides while in the monocrystals it consists of the α-phase; further it shows that in the initial stages of the γ→α+carbides transformation, as well as in the initial stages of the γ→γ+α+carbides, a redistribution of carbon occurs.

Athermal stabilization of austenite E. G. Ramachandran and C. Dasarathy (*Acta Met.*, 1960, **8**, 666–667) A letter. Ranges of temp. of athermal austenite stabilization are arrived at.

On the morphology of proeutectoid cementite R. W. Heckel and H. W. Paxton (*ASM preprint* 215, 1960, 539–554) Three hypereutectoid, plain carbon steels containing 1·20, 1·48, and 1·72 weight %C were solution-treated to give a large austenite grain size and subsequently were isothermally transformed for various lengths of time between 550°C and the Acm temp. The specimens were examined metallographically to observe the effect of experimental variables (C concentration, transformation temp., and transformation time) on the morphology of the precipitated proeutectoid cementite. The morphologies were classified as grain boundary precipitates, Widmanstätten sideplates, intragranular Widmanstätten sideplates, and intragranular idiomorphs.—R. S. F. C.

The displacement of the equilibrium curves of the α- and γ-phases in the Fe–Cr system as a result of long-time heating of the γ-phase at a high temperature A. G. Lesnik and G. V. Khar'kova (*Voprosy Fizika Met. Metalloved.*, 1959, (9), 133–138) High-temp. heating of the γ-phase increases its range of stability, i.e. makes it more stable. Results obtained do not contradict the earlier hypothesis on the appearance of a close packing in experimental alloys as a result of long-time heating. No conclusion can be drawn as to the nature of this close packing.—A. L. P.

The problem of the isothermal transformation of austenite at temperatures below Ms O. Schauber (*Radex Rundsch.*, 1960, (6), 335–342) Particular attention is paid to the processes of formation of martensite, i.e. whether it can be formed only as an athermic process or also isothermally. Examination of heat-treatable and ball-bearing steels showed evidence of isothermal transformation of austenite in a region which is attributable to the martensite stage (18 refs).

The condition of the formation of metastable austenite in iron–carbon alloys Yu. A. Kocherzhinskii (*Voprosy Fiz. Met. Metalloved.*, 1959, (10), 186–199) Experimental results have shown that with a high rate of heating, metastable austenite is formed; the temp. of its formation is usually lower when the grains of cementite in the initial structure are smaller; the extent of the temp. interval changes with a change in the distance between the carbide particles in the initial structure, becoming very small in the absence of structurally free ferrite (30 refs).—A. L. P.

Austenite decomposition E. P. Klier and T. H. Yeh (*Met. Prog.*, 1960, **78**, Oct., 266, 268) Digest of 'The decomposition of austenite in 4340 steel during cooling' (*ASM preprint No.*183, 1960). An earlier paper by Klier showed that the hardenability of AISI 4340 steel could be increased by slow cooling through the critical range before quenching. This phenomenon is investigated in the present work.

Investigating the occurrence of the stabilization of the austenite in phase hardening I. M. Zakher, O. P. Maksimova, A. I. Nikonorova I. M. Plemyannikova, and A. M. Yampol'skii, (*Izvest. Akad. Nauk, Otdel. Tekhn., Met. Toplivo*, 1960, (2), 93–103) Detailed investigations are reported regarding the effect of phase hardening occurring during the direct and reverse martensite transformation on the kinetics of the transformation and on the micro- and submicrostructures of the initial and final phases of Fe–Ni–Mn and Fe–Cr–Ni alloys. It has been found that the effect of phase hardening on the isothermal kinetics of transformation evens out in both types of alloys by a reduction in the 'true' martensite

point, by the displacement of the entire transformation interval to regions of lower temp. and by a sharp decrease in the rate of transformation. The investigation of specimens stabilized by phase hardening has also shown that the changes in structure and properties persist to a very high temp. and are only eliminated at about 1100–1150°.

The effect of the additional stabilization in the anneal of internally hardened austenite O. P. Maksimova, S. Ya. Seredenko, and E. I. Estrin (*Izvest. Akad. Nauk. Otdel. Tekhn., Met. Toplivo*, 1960, (3), 57–65) The effect of the anneal on the resistance of austenite subjected to phase hardening has been studied over a wide range of temp. It has been shown that the state occurring immediately after the reverse martensite change does not correspond to the highest degree of the stabilization of the austenite. This effect may be considerably increased by a subsequent anneal under definite conditions imposed by the phase hardening. The complex nature of the relation between temp. stability of the phase-hardened austenite and since the first of these processes leads to a reduction in the resistance of the austenite and is more rapid than the second, it is possible to interpret this as a non-uniformity in the activation energy in these processes.

The transformation processes in solid bodies, with particular reference to martensite formation R. Mitsche (*Radex Rundsch.*, 1960, (6), 332–334) The conditions of isothermal martensite formation are examined and represented graphically.

The energy relations obtaining during the martensite transformation B. Ya. Lyubov and A. L. Roitburd (*Doklady Akad. Nauk*, 1960, **131,** (2), 303–305) In phase transformations in the solid state, an important role is played by the distortions which accompany the appearance, in the matrix of the original phase, of particles with the new structure. Among the transformations of martensite type occurring during the growth of individual distorted crystals may be mentioned the elastic transformations which can be calculated by the appropriate methods of elasticity theory. This article deals with the mathematical solution of this problem.

The conditions for thermoelastic equilibrium and the effect of external loads on the orientation of the crystals during the martensite transformation B. Ya. Lyubov and A. L. Roitburd (*Doklady Akad. Nauk*, **131,** (3), 552–555) In order to elucidate the mechanism of the martensite transformation and the effect on it of external loads, it is necessary to analyse the stresses appearing in the austenite matrix when the martensite crystals are formed in it. Maintaining the coherence of the phases, as assumed in the article by the same authors (previous abstract), the stress conditions around an isolated martensite crystal can be calculated according to the methods of elasticity theory (*ibid.*, 1958, **120,** (5), 1011) by the same author.

Thermal conditions on the surface of the growing martensite crystal B. Ya. Lyubov and A. L. Roitburd (*Doklady Akad. Nauk*, 1960, **131,** (4), 809–812) The thermodynamical conditions of the growth of the martensite crystal is one of the most important problems of the theory of the martensite transformation since its solution would make it possible to determine the real value of the potential of the process. It is generally thought that the surface temp. of the martensite crystal differs little from that of the surrounding medium and that the martensite transformation may be considered as isothermal, but recently the hypothesis has been put forward of an adiabatic conception of martensite crystal growth. The calculations of the temp. of the surface of the crystal, here explained, point to the fact that if in its initial stages of growth it may be regarded as an isothermal process, at the moment of the complete martensite transformation the conditions on its surface approach adiabatic conditions.

Martensitic transformation in small grains of Fe–Ni alloys G. V. Kurdyumov and L. G. Khandros (*Voprosy Fiz. Met. Metallov.*, 1959, (9), 3–6) In small grains, where the tension should not assist transformation and the grains should be transformed as a whole, less α-phase is formed than in larger grains and in the complete specimen. A suggested explanation is given.—A.L.P.

The change in the austenite state during the martensitic transformation of manganese steel L. G. Khandros (*Voprosy Fiz. Met. Metallov.*, 1959, (9), 7–11) The plastic deformation of crystals is caused by first- and second-order distortions and apparently affects subsequent stages of the transformation. Further experiments are required to explain the mechanism.

Measurement of the heat of transformation in the formation of martensite in iron–nickel alloys by means of a dry ice calorimeter E. Scheil and E. Saftig (*Arch. Eisenh.*, 1960, **31,** Oct., 623–632) A description is given of a calorimeter developed for the continuous measurement of heat content and heat of transformation, and of the determination of these quantities in irreversible Fe–Ni alloys. The results are discussed (24 refs).

Effect of Si and Al on the stability of certain sigma phases K. P. Gupta, N. S. Rajan, and P. A. Beck (*Trans. Met. Soc. AIME*, 1960, **218,** Aug., 617–624) By determining the σ-phase boundaries in the following ternary systems at 1175°C, V–Fe–Si, V–Co–Si, V–Ni–Si, Cr–Mn–Si (at 1000°C), Cr–Co–Si, Cr–Ni–Si, V–Fe–Al, and Cr–Co–Al, it was found that Si exacts a stabilizing effect on these σ-phases, while Al tends to destabilize them. Si atoms in solid solution occupy sites D in the σ-structure. The C_0A_0 ratio increases with increasing Si-, Mn-, or Fe-content. The volume of the unit cell decreases with increasing Si-content.—S.H.-S.

Rate of alloying of metal fuels with stainless steel above 1500°F R. S. Neymark (*Nucl. Eng. Sci. Conference*, 1959, April, 6–9, *Preprint V–89*, pp.14) The rate of alloying between 304 stainless steel and U and Th-base metal fuels was determined between 1600°F and 2300°F. Within this range, the Fe–U eutectic forms more rapidly than the Fe–Th eutectic.—C.F.C.

Observation of slip, twinning, and cleavage in iron–phosphorus solid solutions E. Hornbogen (*Trans. Met. Soc. AIME*, 1960, **218,** Aug., 634–635) The deformation mechanisms of α-iron–phosphorus alloys were compared at 20° and −196°C. Alloying with P increases resistance to slip, but has little effect on that to twinning. Stress for onset of twinning is nearly independent of temp. but there is an increasing tendency for cleavage along [112] twin boundaries with decreasing temp. and increasing P content.—S.H.-S.

Constitution of Fe–C–Mo alloys containing 0·05–1·3%C and 0·03–6·0%Mo R. F. Campbell, S. H. Reynolds, L. W. Ballard, and K. G. Carroll (*Trans. Met. Soc. AIME*, 1960, **218,** Aug., 723–732) Based on metallographic and X-ray data, probable equilibrium conditions from 1340–2400°F are presented for the composition range investigated, and are correlated with investigations of Takei and Kuo. Provision is made for existence of Mo_2C and $(Fe_1Mo)_{23}C_6$ carbides heretofore omitted in diagrams in this composition range. These carbides and $(Fe_1Mo)_6C$, in equilibrium with ferrite and austenite, restrict the austenite and (austenite + ferrite) fields to lower carbon contents and higher temp. than in the Fe–C system. —S.H.-S.

CORROSION

The rusting of cast iron H. H. Collins (*BCIRA J.*, 1960, **8,** Sept., 742–750) Various examples of formation of rust are given and illustrated, and a brief outline of the chemical process involved is presented; especially the factors which affect the point of precipitation of rust are described, and the way in which a rust film may protect iron from further corrosion is explained. Four major ways of relieving causes of corrosion are indicated.—S.H.-S.

Corrosion of iron and steel. Report of Committee A–5 (*ASTM Preprint* 3, 1960, pp.18 A sub-committee report on the following: tests after exposure to atmosphere; life of corrugated galvanized and black sheet, exposed since 1926; inspection of hardware, structural shapes, etc., exposed since 1929; and inspection of hardware galvanized by different methods and exposed on three sites since 1958. Details are given of a proposed tentative specification for zinc-coated (galvanized) iron and steel sheets for culverts and underdrains.—J.W.J.

The corrosion of steel in the atmosphere A. A. Babakov and D. G. Tufanov (*Zhur. Prikl. Khim.*, 1960, **33,** (6), 1334–1340) The rate of corrosion of steel in the atmosphere which depends on its chemical composition and structure has been established. The composition of steel appreciably affects the rate of corrosion; all low-alloy steels are superior in this respect to carbon steels. The data given here should be considered as of a preliminary nature since the majority of the specimens were under investigation for less than 7–10 years.

Corrosion in the boiler cycle B. P. Butler (*Corros. Eng.*, 1960, **2,** July, i–viii; *Corr. Prev.*, 1960, **7,** July) A paper, delivered before the Brit. Assoc. of Corrosion Engineers in S. Kensington, London, reviews operation costs, industrial plant, the hot well, feed lines and economizers, the boiler itself, steam and condensate line corrosion, contamination of feed water, and corrosion outside the boiler, with suggestions for control by the aerosol method.

Low alloy corrosion resistant steels E. Herzog (*Mét. Constr. Mécan.*, 1960, **92,** Nov., 915–929) A review of the effect of corrosion in industrial centres, in marine environments, and in natural sea water. Various examples of corrosion under strain are examined, and the role of carbon and the basic principles affecting the manufacture of corrosion resistant steels are discussed.—S.H.-S.

Effect of temperature on the nature of the corrosive destruction of stainless steels in acid solutions A. I. Glukhova (*Zhurn. Prikl. Khim.*, 1960, **33,** (8), 1853–1861) The temp. of a 0·1 N solution of HCl and of a 10 N solution of HNO_3 determines the ratio between the uniform and the intercrystalline corrosion of 2Kh18N9 steel. The intercrystalline corrosion is conditioned by the common action of two factors, temp. and time.

Preferential corrosion of stabilized stainless steel welds C. L. Angerman and P. M. Kranzlein (*ASM preprint* 208, 1960, 433–446; also digest in *Met. Prog.*, 1960, **78,** Oct., 262, 264) Electron metallography of weldments of Types 3098Cb, 347, and 321 stainless steels after short-term corrosion in a 3·0M HNO_3–0·075M HF solution and in 65% HNO_3 revealed that the attack occurred by preferential dissolution of NbC or TiC particles located along the dendrite boundaries in the weld. This mechanism was in contrast to the attack of grain boundaries adjacent to $Cr_{23}C_6$ particles in sensitized 304 steel. The presence of sigma phase in weldments heat-treated at 1650°F (900°C) did not increase the corrosion rate over that observed for the as-welded condition in which sigma phase was not detected.

The effect of the chemical composition of the electrolyte on the anode behaviour of low carbon steel V. V. Gerasimov and A. I. Gromova (*Zhurn. Prikl. Khim.*, 1960, **33,** (7), 1563–1567) In the course of investigating the kinetics of the processes at the electrodes of type 40 steel in a N solution of NaCl, Na_2SO_4, and Na_2SO_3, it has been found that the rate of the anode reactions at a constant potential is the same for all the solutions investigated. The rate of the cathode process in Na_2SO_4 and NaCl solutions is conditioned by the rate of oxygen diffusion to the metal surface and in the case of Na_2SO_3 solutions by the rate of oxygen diffusion and by the discharge of hydrogen ions.

The corrosion of iron in acids in the presence of oxidizers and inhibitors I. P. Anoshchenko (*Zhurn. Prikl. Khim.*, 1960, **33,** (6), 1421–1422) Ions of the ferrous iron originating during the solution of metallic iron are oxidized to ferric ions under the action of the oxygen of the atmosphere. The ferric ions play a double role; a fraction is adsorbed on the surface of the metallic iron and the rest acts as depolarizer (being reduced to ferrous ion by the electrons which become free when the metallic iron is ionized). The ferrous ions are also adsorbed on the surface of the metallic iron in the same way as other cathode metals of much lower electrode potential than iron. The action of mixtures of $CaBr_2$, hexamethylenetetramine,

atebrin, and $SnCl_2$ on the corrosion of iron were investigated in an atmosphere of oxygen so as to conserve the maximum of ferric cations. The findings are tabulated.

The transformation of a uniform into scabbing corrosion during high temperature oxidation of a cyclically stressed metal E. L. Kazimirovskaya and A. V. Ryabchenkov (*Zhurn. Prikl. Khim.*, 1960, **33**, (4), 841–845) Cyclical stresses transform a uniform into a localized corrosion, changing simultaneously the chemical composition of the corrosion products. In the transition from dry to moist air mixtures (with SO_2) the overall corrosion increases, not because of the formation of sulphides, which on the contrary decreases, but because of an increase in the rate of oxide formation. In moist air mixtures, therefore, the ratio between the quantity of sulphides and possibly of other metal compounds with sulphur, and the quantity of oxides in the scale is appreciably reduced and diminishes with time more rapidly than in a dry air mixture. This is shown by the mechanical properties of the film and is also confirmed by the fact that in mixtures of moist air with sulphurous gases, no ulcer-like corrosion develops on the surface of the stressed specimens. Under such conditions the film is not subjected to local destruction through which sulphur gases can be in continuous contact with the metal.

The action of metal cations on the corrosion of iron in sulphuric acid at high temperatures I. P. Anoshchenko (*Zhurn. Prikl. Khim.*, 1960, **33**, (5), 1146–1150) The iron under investigation contained 0·04%C; 0·123%Mn; 0·02%Si; 0·02%S, and 0·021%P. The 10 mm dia × 10 mm high specimens were thoroughly cleaned before the tests which were carried out in a special apparatus designed by the author, and the experiments determined the volume–weight changes and established the polarization curves. The tests were carried out in pure 3N H_2SO_4 with or without $Al_2(SO_4)_3$ additions. The effect of the following cations was also studied: (in order of increasing normal potential), K, Ca, Na, Sr, Mg, Al, Zn, Cd, Co, Ni, Sn, Sb, and Bi introduced in the form of the corresponding salts in concentrations of 3 mg mol/l. Tests were made at 20, 40, 60, and 80°C. It appears that the cations of all the metals, independent of their position in the electrochemical series can be adsorbed on the surface of the iron.

Corrosion cracking of 1Kh18N9 steel in chlorides in the presence of organic inhibitors N. I. Podobaev and S. A. Balezin (*Zhurn. Prikl. Khim.*, 1960, **33**, (10), 2290–2300) A new inhibitor, Katapin (*p*-dodecylbenzylpyridinium chloride) and also the I–1–A inhibitor retard corrosion cracking of this steel in a 42% $MgCl_2$ solution at 153° but do not inhibit it altogether. Katapin is an inhibitor with a mixed action but predominantly acts by disturbing the anode process.

Corrosion of stressed steel in nitric acid V. A. Titov (*Zhurn. Prikl. Khim.*, 1960, **33**, (2), 402–408) Under reversible stresses the destruction of the metal in HNO_3 depends largely on the concentration. Below 1%, the destruction of the metal is conditioned chiefly by its resistance to mechanical fatigue. In concentrations from 1 to 10% the metal is destroyed under the combined action of mechanical and electrochemical factors. In higher concentrations, from 10 to 55% the mechanical factor loses its importance and the metal is destroyed mainly as a result of chemical solution. In the passivation concentrations investigated by us (55–60%), the metal is destroyed by corrosion fatigue.

Intercrystalline corrosion of 1Kh18N9T steel in water vapour V. V. Gerasimov and K. A. Popova (*Metalloved. Term. Obra. Met.*, 1960, (1), 13–14) The results of the investigation show that this steel displays a tendency to intercrystalline corrosion when tested according to GOST 6032–51, this corrosion does not develop in all media, and it develops more rapidly in chemically active media. It appears that the Cr-impoverished grain boundaries are in a passive state in distilled water and in water vapour at the critical point.

The tendency of OKh23N28M3D3 (EI 943) steel to intercrystalline corrosion E. V. Zotova (*Metalloved. Term. Obra. Met.*, 1960, (1), 15–17) The steel investigated, from normal production as delivered (quenching from 1 100° and subsequently heated to 700° with 20 min holding) is not subject to intercrystalline corrosion in any of the solutions investigated. Independent of the method of testing, the steel which has been quenched from a high temp. is more prone to intercrystalline failure after a holding of 120 min in the subsequent tempering. The greatest tendency to intercrystalline failure after quenching from high temp. is related to the dissolution of a fraction of the titanium carbides in the austenite and the subsequent impoverishment of the sections along the boundaries in Cr during tempering.

Corrosion in the chemical industry. Part I. Selection of materials of construction C. W. Brewer (*Min. Chem. Eng. Rev.*, 1960, **52**, June 15, 52–55) A brief survey of designing, literature, and corrosion testing, with a comparison of plant and laboratory immersion tests, and suggestions as to selection of construction material. **2. Metallic materials of construction for the chemical industry** (July 15, 58–61) A brief account, mainly of iron and ferrous alloys, with notes on welding.

Alloy steel chains in marine application S. L. Gertsman (*Canad. Dept. Mines Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 33) Tests in the Bay of Fundy are briefly referred to. Pitting corrosion occurred on all samples recovered.

The corrosion of road vehicle engines by anti-freeze solutions. 2 H. H. Collins and R. I. Higgins (*Corr. Prev.*, 1960, **7**, March, 41–48) For the determination of glycol oxidation rate and consequent rate of corrosion of iron in vehicle engines, a schematic layout of test rig and an actual laboratory test rig are presented and described. Numerous test results are tabulated and discussed and conclusions as to the factors responsible for rapid oxidation of glycol in anti-freeze solutions with a resulting rapid rate of corrosion in cast iron and steel engine components, especially in heavy duty diesel engined vehicles. An appendix with analytical methods for anti-freeze solutions is added.—S.H.-S.

Surface films on annealed stainless steels J. H. Waxweiler (*Met. Prog.*, 1960, **78**, Sept., 80–83) The darkening of the surface film of stainless steels which are bright annealed with H_2, as the dew point of the gas rises, is shown by spectrophotometer and X-ray diffraction tests to be due to increasing amounts of Cr oxide in the film.

Low temperature corrosion of oil-fired boilers A. Denis (*Corros. et Anticorros.*, 1960, **8**, Oct., 347–358) A general review of materials and protective coatings for metallic surfaces, of additives both as neutralizers and inhibitors of aggressive corrosion by H_2SO_4 acid with a view to the elimination of the sulphur content of the oil fuel is presented. The use of shot blasting is discussed.—S.H.-S.

The oxidation of iron in carbon dioxide–carbon monoxide atmospheres W. W. Smeltzer (*Trans. Met. Soc. AIME*, 1960, **218**, Aug., 674–681) The linear formation rates of wustite films have been determined over the temp. range 590–1 030°C, using a vacuum microbalance technique. These rates are dependent directly on the partial pressure of CO_2. Activation energies for film and scale formation in CO_2 and O_2 atmospheres are equivalent to either the dissociation energies of CO_2 and O_2, or the activation energy for the diffusion of cation vacancies in wustite.—S.H.-S.

Rapid intergranular oxidation of 18–8 stainless steels by oxygen and dry sodium chloride at elevated temperatures H. W. Pickering, F. H. Beck, and M. G. Fontana (*ASM preprint* 232, 1960, 793–803; also digest in *Met. Prog.*, 1960, **78**, Oct., 200, 204) Rapid oxidation in the range 1 100–1 400°F may be due to formation of a non-protective chromate scale. 0·08C steel is attacked more rapidly than lower-C specimens. Ferritic steels are not susceptible. Attack by NaF is much more rapid and by NaBr much less.

The penetration of sulphur in corrosion into steels placed under tension in sodium sulphide E. Hertzog and L. Bäcker (*Compt. Rend.*, 1960, **251**, Oct. 17, 1633–1635) Tempered steels rapidly break in Na_2S. Little change of properties and no appreciable H_2 uptake occurs and a direct action of S seems to occur. Tests making use of ^{35}S were made and considerable penetration and sulphurizing of the surface layers was found. Thin Al–Si coatings and other plated films prevented penetration. Further work in acid solutions will be reported.

The structure of nitrided 15Kh11MF steel after holding at high temperatures A. V. Kostenko, E. V. Lopukhina, T. M. Pogrebetskaya, and A. A. Yurgenson (*Metalloved. Term. Obra. Met.*, 1960, (7), 48–52) After long exposure at 570°C, scale appears on the surface of 15Kh11MF steel. The iron nitride oxidizes first. The nitrides form solid solutions by replacement with a wide range of homogeneity having a lattice with a considerable number of vacancies. Carbon easily diffuses through such solid solutions.

The examination of oxide scales on iron–chromium alloys by X-ray scanning micro-analysis G. C. Wood and D. A. Melford (*JISI*, 1961, **198**, June, 142–148) [This issue].

A method of calculating the formation of iron oxide deposits on the internal heating surface of high pressure steam boilers N. N. Man'kina, A. G. Tkachenko, and L. G. Buinovskaya (*Teploenergetika*, 1960, (9), 30–34) Methods now in use consist in examining sections of baffle tubes arranged in the positions of the greatest heat loads and assessing the condition of the internal surfaces of the boilers owing to the deposit of iron oxides. A much simpler and more rapid method is proposed, although it is less precise. It is based on a balance between the input and output of the boiler. It may be summarized as follows: The product of the quantity of water in t/h fed to the boiler with its salt content (in mg/l) must equal the product of the quantity of steam in t/h and the salt content of the boiler water in mg/l plus the difference, which represents the deposit on the boiler in g/h. Practical examples are given which show results with a tolerable margin of error.

Resistance of gas turbine metals to vanadate corrosion R. A. Lipshtein, S. E. Khaikina, and E. S. Ginsburg (*Teploenergetika*, 1960, (8), 57–60) The corrosion due to the chemically active deposits depends on the V and Na contents and the ratio between them. Deposits drawn from oil-fuel gas turbines show a varying degree of corrosion depending on the V_2O_5 content of the fuels. With a ratio closely corresponding to a test mixture of V_2O_5 and Na_2SO_4, all steels investigated, and also the Nimonic alloys, do not give long corrosion-free service at temp. above 650°.

On the establishment of scales of corrosion on steels covered by protective coatings of many layers, resulting from the application of varnishes, paints, and like preparations H. Rabaté (*Pein. Pig. Ver.*, 1960, **36**, Dec., 697–699) This editorial, after a brief reference to common types of rust or corrosion on bare and painted steels, recapitulates the programme of the European Corrosion Commission for its meeting in Paris on 26 and 27 Oct. 1960, and after a brief reference to the activities of other bodies on the subject in various countries between 1941 and 1956, suggests that the Commission's findings embody, in brief, three recommendations of methods to be followed, (a) planimetric, (b) reflectometric, and (c) gravimetric, with a promise of later publication, in full textural detail, of the decisions taken by the Commission.—S.H.-S.

Study on the corrosion of stainless steels in high temperature gas. I. Corrosion of 18 Cr–8Ni stainless steel in carbon dioxide T. Yanagihara, G. Shimaoka, S. Ikeda, H. Suzuki, and A. Takei (*Trans. Nat. Res. Inst. Met.*, 1960, **2**, (1), 43–50) Corrosion behaviours of 18Cr–8Ni stainless steel heated at 200° to 1 000°C in CO_2 were studied both by electron diffraction and by the electron microscope. At temp. near 300° the surface of the steel began to be covered with straw-coloured films, and corrosion reaction proceeded with growth of surface films at higher temp. Rupture of surface scales appeared at temp. above 900°C. Electron diffraction and electron microscopical results showed that the principal components of the surface films were γ-$(Fe, Cr)_2O_3$ or Fe_3O_4 at

200° to 400°C, Cr_2O_3 at 500° to 600°C, and $FeCr_2O_4$ or $NiCr_2O_4$ at 700° to 1000°C. These results are very similar to those of high-temp. oxidation of 18–8 stainless steel in low pressure of air, and also indicate that oxidation reaction is predominant in the corrosion process by CO_2.—S.H.-S.

Corrosion of welds in austenitic stainless 18–8 type steel in fuming nitric acid M. L. J. Bernard and N. Flavian (*Corros. et Anticorros.*, 1960, **8**, Oct., 359–370) Tests are described on two classes of welded stainless steel, one of low carbon content, the other stabilized by Ti. The low carbon steels showed excellent resistance to intergranular corrosion at the level of welds, while the Ti type steels showed a knife-edge corrosion on the length of welds.—S.H.-S.

The effect of oxygen on the corrosion and electrochemical behaviour of 1Kh18N9T steel in water at the critical point V. V. Gerasimov, A. I. Gromova, and E. T. Shapovalov (*Doklady Akad. Nauk*, 1960, **130**, (5), 1089–1090) The investigation of the process at the electrodes of this steel in distilled water at 300° and 87 atm pressure was carried out in an autoclave as explained in the *Zavods. Lab.*, 1958, (1), by the same authors. Anode and cathode polarization curves are given. With an increase of the oxygen in the water the rate of cathode ionization of the oxygen increases, as does also the value of the limiting diffusion current strength. This increase causes displacement towards the positive side of the stationary potential. In the case of anode polarization curves, a displacement of the stationary potential for this steel towards the positive side means an increase in the rate of corrosion.

Changes in the structure and composition of the surface layers of steel under the influence of a stream of high-temperature compressed gases V. F. Yankevich (*Trenie i Iznos v Mashinakh*, **14**, 1960, *Akad Nauk*, 171–184) The paper describes an investigation of the surface layer of piston rings of aero engines and of the destruction of the piston rings by erosion. This erosion was caused by the action of gases passing through slits between the ring and the cylinder as a result of poor assembly. A change in the composition of the surface layers of the metal, the formation of highly dispersed structures consisting of carbides, and plastic deformation of the surface layers were observed. An explanation is suggested for the change in composition.—A.I.F.

The effect of chromium concentration of the iron–chromium alloys on their electro-chemical behaviour and corrosion properties G. M. Florianovich and Ya. M. Kolotyrkin (*Doklady Akad. Nauk*, 1960, **130**, (3), 585–588) Similar to the experimental findings regarding different metals and alloys, the curves of the relation between the solution process of the Fe–Cr alloys and potential are characterized in all cases by the existence of definite domains, viz: the domains of active solution, of the first limiting current strength, of passivation, of the passive state, of over-passivation, and of the second limiting current strength as it appears on the graphs. The anodic passivation of iron causes a reduction in the rate of solution in comparison with the first domain of limiting current strength. Alloys with low Cr content (below 4%) are subject to still more difficult anode passivation. In these cases the curves corresponding to the passivation domains are missing.

The effect of anode polarization on the intercrystalline corrosion of stainless chromium–nickel steels N. D. Tomashov, G. P. Chernova, and O. N. Markova (*Zhurn. Prikl. Khim.*, 1960, **33**, (6), 1324–1334) The passive domain of quenched and tempered 2Kh18N9 steel in H_2SO_4 has been determined. It should be noted that this steel, when tempered, has a narrower range of stable passivation as compared with the hardened state owing to the intercrystalline corrosion which takes place during the transition from the active to the passive condition. In a solution of 160 g $CuSO_4$. $5H_2O$+100 cm^3 H_2SO_4 (d=1·84)+1000 ml H_2O+Cu (chips) and in solutions of 10%HNO_3+1 or 2%NaF, protection from intercrystalline corrosion is possible by means of anode polarization in the domain of the passivation potential values.

Fretting corrosion S. L. Gerstman (*Consad. Dept. Mines, Techn. Surv., Phys. Met. Div., Res. Special Proj. Rept.*, 1960, Jan. 15, 26–27) New apparatus and new methods of assessing damage have been developed.

Stress corrosion of austenitic stainless steel D. van Rooyen (*J. Met.*, 1960, **12**, Oct., 812–813) A review of the literature (13 refs).

Mechanism of corrosion protection by 'wash primer' treatment and phosphating K. S. Rajagopalan and K. Balakrishnan (*J. Sci. Ind. Res.*, 1960, **19B**, June, 220–221) A letter. Polarization curves on varnished pretreated steel are shown and interpreted.—S.H.-S.

Design for minimum corrosion in 'Composite' engines A. M. Montgomery (*SAE J.*, 1960, Aug., 46–47) Results of a study where Al cylinder heads are mounted on cast-iron blocks are reported. Useful hints are given which would result in a decrease in galvanic corrosion, erosion, and cavitation.—A.H.M.

The amine salts of some inorganic acids as inhibitors of the atmospheric corrosion of metals S. A. Gintsberg and A. V. Shreider (*Zhurn. Prikl. Khim.*, 1960, **33**, (10), 2366–2368) Triethanolamine molybdate, monoethanolamine tungstate, monoethanolamine borate, and triethanolamine phosphate have been investigated regarding their corrosion-inhibiting properties, and the findings are tabulated.

The effect of corrosion inhibitors on the corrosion-cracking of 1Kh18N steel at 153° in boiling $MgCl_2$ solution S. A. Balezin and N. I. Podobaev (*Zhurn. Prikl. Khim.*, 1960, **33**, (6), 1300–1311) The action of a number of inhibitors mixed in different proportions with boiling $MgCl_2$ solution on corrosion cracking of this steel has been investigated and the results are tabulated.

Joint action of some inhibitors on the corrosion of steel in acids I. P. Anoshchenko (*Zhurn. Prikl. Khim.*, 1960, **33**, (6), 1319–1324) The shielding action of inhibitors increases with increasing temp., as the overvoltage of liberated hydrogen falls under these conditions and the proportion of H_2 depolarization increases. The rate of corrosion should increase under these conditions. In fact, it does so in pure acid solutions without inhibitors. In the presence of inhibitors the hydrogen overvoltage increases, the proportion of hydrogen depolarization diminishes and that of the oxygen increases proportionately.

Pitting inhibitor H. G. Chen (*Zhurn. Prikl. Khim.*, 1960, **33**, (10), 2300–2305) The KX (coke–chemical) inhibitor effectively retards pitting corrosion in electrolyte solutions under normal conditions. In the course of investigations of the development of pitting it has been found that many inorganic passivation agents promote the formation of protecting films on the surface of the metal in conjunction with chloride ions, which then destroy these films and promote the growth and deepen the pits. The KX inhibitor, in a chemically active medium, inhibits pitting completely at ordinary temp. and also in boiling solutions, but in the latter case it increases the uniform corrosion of the heated metal surface.

A contribution to the explanation of intergranular corrosion of chromium–nickel steel V. Cihal and M. Prazak (*Corrosion*, 1960, **16**, Oct., 530t–532t) The authors discuss the theory of intercrystalline corrosion in Cr–Ni steels, and give experimental results to verify the theoretical assumptions. The extent of the corrosion is shown to depend on the amount of precipitated chromium carbide and on the redox potential of the solution.—G.F.

Qualitative mechanism of stress corrosion cracking of austenitic stainless steels D. van Rooyen (*Corrosion*, 1960, **16**, Sept., 421t–429t) The author gives the results obtained with several metals in studies of cracking while observing electrochemical potential changes, extension during cracking, and the sound generated on failure. Stress-corrosion crack propagation in stainless and mild steels is relatively slow and consistent with an electrochemical theory.—G.F.

A quantitative method for determining the effects of alloying constituents on the film formation properties of different steels D. G. Schweitzer (*PNL–4356*, 1958, Feb., pp.12; from *Nucl. Sci Abs.*, 1959, **13**, Nov. 30, 2704) Corrosion resistance of steels to Bi is in part due to the formation of insoluble films of ZrN, ZrC, or combinations of the two on the steel surfaces. The best possible solution to the corrosion problem as far as film formation is involved will be obtained by determining which steel produces the best 'performing' film.

Stress corrosion in stainless steels—effect of potential difference between liquid and metal S. Brennert (*Jernkont. Ann.*, 1960, **144**, (7), 560–566) Experiments are described to examine the rate of corrosion at different constant potentials irrespective of their method of production. Tests were carried out on 18–8 wire in $CaCl_2$ soln., at 100° or 135°C, at 20 or 100 kg/mm^2. The results are discussed.

Deterioration of materials in polluted atmospheres J. E. Yocom (*Corrosion*, 1959, **15**, Oct., 541t–545t) The author discusses the chemical and physical aspects of polluted atmospheres, dealing specifically with the detrimental effects of air pollutants on metals and other materials.—G.F.

Corrosion by urban cooling waters S. Sussman (*Corrosion*, 1960, **16**, Oct., 471t–472t) Untreated circulating cooling waters are compared with make-up waters for eight Eastern USA cities for such factors as pH, alkalinity, chloride content, sulphate/chloride ratio, and corrosion products.—G.F.

Corrosion of metals in tropical environments. Part 4. Wrought iron C. R. Southwell, B. W. Forgeson, and A. L. Alexander (*Corrosion*, 1960, **16**, Oct., 512t–518t) The authors discuss the corrosion of Aston process wrought iron exposed to five natural environments in the tropics. The results indicate that corrosion proceeds at the greatest rate during continuous immersion in sea water, and at lesser and nearly equal rates in fresh water and at mean tide level.—G.F.

Corrosion of type 202 stainless steel in high temperature water A. P. Larrick (*HW–62820*, 1959, Dec., pp.8; from *Nucl. Sci. Abs.*, 1960, **14**, Sept. 15, 2159) Two heats of 202 stainless steel and one heat of 304 stainless steel were corrosion tested in a recirculating loop using pH10 water at 290°C. Corrosion rates for both alloys were found to be 0·0044 mils/year.

Corrosion behaviour of Al–Fe–Ni in water at high temperature after an extended heat treatment. Effects of Ti and Zr additions P. Lelong, J. Noisan, and J. Hérenguel (*CDRA–196*, 1959, Sept. 10, pp.25; from *Nucl. Sci. Abs.*, 1960, **14**, Aug. 31, 2018) A study was made of the corrosion of 1%Ni–1%Fe–Al with trace additions of Ti and Zr by water at 350°C for 10 h. These alloys undergo a noticeable coalescence in these conditions with a progressively diminishing corrosion resistance. Intergranular corrosion, suppressed by the Ni, reappears. The Ti and Zr additions effectively prevent the effects of prolonged exposure. The Zr enters into the complex intermetallic compounds and modifies the corrosion mechanism.

Corrosion in hydrogen sulphide water systems J. A. Snyder and D. Warren (*DP96*, 1957, pp.240; from *Nucl. Sci. Abs.*, 1959, **13**, Nov. 30, 2704) A detailed report is presented of the corrosion test work on the behaviour of materials of construction in the H_2S–H_2O system.

Effect of reactor radiation on the corrosion of stainless steel by fissioning solutions F. J. Sweeton (*CF–53–3–276* (Pt.I) (Del.), pp.144–147; from *Nucl. Sci. Abs.*, 1960, **14**, Aug. 15, 1908) A method used at ORNL to study the corrosion of materials by homogeneous reactor solutions in the presence of a neutron flux is described. The effort was mainly confined to UO_2SO_4 solutions in type 347 stainless steel at a temp. of 250°C.—S.H.-S.

Corrosion wear of cylinder liners of diesel engines using residual oil G. Simonetti (*Corros. Techn.*, 1960, **7**, Oct., 315–319, 334) The formation of H_2SO_3 in the oil, its corrosive action, and means of inhibiting the formation of SO_2 or the neutralization of H_2SO_4 are discussed, and the properties and effects on wear of anti-corrosive oils are considered, with examples.

Stainless steel corrosion by dilute nitric acid at elevated temperatures and pressures M. L. Pearce and V. S. Griffiths (*Corros. Techn.*, 1960, **7**, May, 142–146, 162) The corrosion of

stainless steel (18–8) in 0·01–1·4%HNO_3 at 300°–350°C is investigated. Passivity was found at 300°C. No effects of temp. increase or small amounts of oxidizing ions on corrosion rate were observed, but the rate was increased in the presence of 10 g/l U as uranyl nitrate. Corrosion in the vapour phase was slight, but severe corrosion occurred at the vapour/liquid interface (11 refs).

Heating conditions and resultant scales on mild steel T. Otake, K. Aoki, and T. Fujishima (*Nippon Kinozku*, 1960, **24**, (2), 92–96) Experiments on four kinds of mild steel, varying in degree of deoxydation but constant in %C, show that the properties of scale are influenced by heating temp., atmosphere, and Si content of the specimen, and the structure of subscales and the depth of oxidation by the Si content.—K.E.J.

Oxidation of steel heated in carbon dioxide under pressure R. Darras, D. Leclercq, and C. Bunard (*A/CONF.15/P/1148*, pp.16; from *Nucl. Sci. Abs.*, 1959, **13**, April 30, 906) [In French] Observed weight increases in low-alloy steel specimens heated up to 400°C in CO_2 under pressure were small even after 1000 h, and the oxidation curve was linear. Passivation treatments appear to influence the behaviour of the steel in CO_2 atmospheres.

The mechanism of oxidation of iron in carbon monoxide–carbon dioxide mixtures F. Pettit, R. Yinger, and J. B. Wagner jun. (*Acta Met.*, 1960, **8**, Sept., 617–623) A study in the temp. range 925°–1075°C. The problem is stated mathematically, the experimental chamber is described, and data are presented and results are discussed.—S.H.-S.

High temperature oxide films formed on shot-peened Fe–Al alloys T. Nakayama (*Nippon Kinzoku*, 1959, **23**, Dec., 739–742) Films formed at 700° and 1000°C on 8·86–22·50%Al alloys were examined. In general, furnace-cooled alloys oxidized at 700°C had α-Fe_2O_3 on the surface, those oxidized at 1000°C had α-Al_2O_3, and shot-peened specimens had γ-Al_2O_3. Shot peened alloys thus behave like water-quenched ones.—K.E.J.

Investigation of Fe–Mn–Cr–N–C system for heat-resistance and oxidation resistance between 1200°F and 2000°F J. P. Tarwater and E. J. Dulis (*AD–203523, PB 151558*, 1958, pp.115; from *US Res. Rep.*, 1959, **31**, May 15) Austenitic Mn–Cr–N–C steels, with various amounts of V, Nb, W, and Cr–Mo, after suitable heat treatment had very good room- and high-temp. tensile and creep-rupture properties. Effects of Ca and Si additions, and rolling properties of the steels, were described (11 refs).

Determination of oxygen in oxide films by neutron activation analysis J. W. Winchester, R. E. Meyer, L. C. Bate, and G. W. Leddicotte (*CF–59–7–128*, 1959, July 15, pp.6; from *Nucl. Sci. Abs.*, 1960, **14**, Aug. 31, 1973) The reactions ^6Li (n, α)^3H and $^{16}O(^3H, n)^{18}F$ were tested as possibly useful for measurements on oxide films. If chemical separation were carried out it appeared that the method might be used.

Corrosion evaluation tests of: I. Austenitic stainless steel. II. Welded austenitic stainless steel A. P. Krijff and A. De Visser (*IGRL–T/C–109*, translated from *Smit Mededel*, 1954, **9**, 38–49, 79–87, pp.30; from *Nucl. Sci. Abs.*, 1960, **14**, Oct. 15, 2491) The laboratory methods of corrosion testing of austenitic stainless steels are reviewed, and the advantages of the boiling HNO_3 metallurgical test are outlined. The results of laboratory tests on different types of stainless steel plate material are discussed. A survey on the method of corrosion testing of welded austenitic stainless steel is presented. The influence of plate material properties on the test results is outlined, as well as the influence of plate thickness.

Examination of corrosion specimens from slurry blanket mockup runs SM–6 through SM–9 R. B. Gallaher, S. A. Reed, and G. G. Warner (*CF–60–5–137*, 1960, May, pp.12; from *Nucl. Sci. Abs.*, 1960, **14**, Oct. 15, 2491) Low attack rates (0·1 to 0·5 mpy) were displayed by coupon specimens of type 347 stainless steel, Ti RC–55, and Zircaloy-2 which were exposed for 2877·5 h in an oxygenated slurry of Th-8%U oxide, 116·5 h in water, 6·9 h in 5%HNO_3, and 4·3 h in 3%Na_3PO_4 during runs SM-6 through SM-9 in the slurry blanket mockup. The leading coupon of type 347 stainless steel showed a slightly higher rate than the other stainless steel coupons due to entrance effects. Specimens of SA–212–B carbon steel displayed average attack rates of 2·9 mpy.—C.F.-C.

Determination of a phase diagram for the system metal-electrolyte T. Marković and M. Sevdić (*Werks. Korros.*, 1960, **11**, Oct., 622–626) The corrosion reaction is followed on the basis of theoretical and experimental results and an expression derived for rate of corrosion.

Design and interpretation of atmospheric corrosion tests H. R. Copson (*Corrosion*, 1959, **15**, Oct., 533t–541t) The author discusses the principles and procedures employed in the design and interpretation of atmospheric corrosion tests, and considers how to make the tests more useful and informative.—G.F.

Preliminary evaluation of the cracking tendencies of hardened type 410 stainless steel M. A. Golik and I. H. Welinsky (*WAPD CTA(MEE)–421*, 1958, Feb., pp.4; includes attachment: **Minutes of meetings—Corrosion studies on hardened AISI 410 steel** I. H. Welinsky (1958, Jan., pp.5; from *Nucl. Sci. Abs.*, 1958, **12**, Dec., 15 2141) The current activities on the investigation of stress corrosion characteristics of hardened type-410 stainless steel are reviewed.—C.F.C.

Development of thin metal film corrosion indicators D. Roller and G. H. Rohrback (*Corrosion*, 1960, **16**, Aug., 399 t–404t) The authors describe the development of visual and electrical corrosion indicators which utilize thin metal films vacuum-deposited on non-metallic substrates, and present data showing the behaviour of these indicators in corrosive atmospheres.—G.F.

Concentration cells and aqueous corrosion E. Schaschl and G. A. Marsh (*Corrosion*, 1960, **16**, Sept., 461t–467t) The authors have developed a new technique for studying simple and complex concentration cells, and have used it to determine some of the principles of cell action. The technique is also applied in the split cell method of studying corrosion inhibitors.—G.F.

Effect of pH in the range 6·6–14·0+ on the aerobic corrosion fatigue of steel F. J. Radd, L. H. Crowder, and L. H. Wolfe (*Corrosion*, 1960, **16**, Aug., 415t–418t) The aerobic corrosion fatigue performance of a normalized AISI 1036 steel has been studied in a 3%NaCl solution of various pH levels, and the results are summarized in fatigue curve form. Special corrosion phenomena are recorded, and possible control measures are suggested.—G.F.

Laboratory investigation of water-side scale and corrosion in the presence of high process-side temperatures H. Kerst (*Corrosion*, 1960, **16**, Oct., 523t–529t) The author describes a laboratory method of testing water-side corrosion and scale deposition in the presence of high process-side temp. Experimental results with two types of specimen are given.—G.F.

Estimating the cost of corrosion in refining crude units N. J. Landis (*Corrosion*, 1960, **16**, Oct., 479t–486t) The author presents a detailed study of the cost of corrosion in refining crude oil distillation units. Capital, maintenance, and operating costs are all considered, and the actual corrosion cost is significantly less than prior estimates by the industry would have predicted.—G.F.

Influence of addition elements on corrosion resistance of chromium–nickel, molybdenum, copper steels in sulphuric acid solutions E. V. Sotova (*Khim. Prom.*, 1958, 239–243; *CEA–tr–R–696*, pp.15; from *Nucl. Sci. Abs.*, 1959, **13**, Nov. 30, 2712) The results of the investigation showed that Cr, Ni, Mo, and Cu improve the corrosion resistance to a great degree but Ti, Nb, and C have no effect. The conditions under which the metals improve corrosion resistance are given. The steels having 5 to 9%Cr and 15%Ni display a fissuring corrosion in 5 to 60%H_2SO_4. The austenite–martensite two-phase steels have a much better corrosion resistance in 30% acid at 80°C than the single-phase austenite steels.

Compatibility of reactor materials in flowing sodium M. Davis and A. Draycott (*A/CONF. 15/P/25*, pp.36; from *Nucl. Sci. Abs.*, 1959, **13**, April 30, 901) Validity of various types of compatibility tests is discussed, and the application of typical corrosion testing equipment to radioactive mass-transfer measurements reviewed. Variables studied include specimen temp., velocity of liquid flow over the specimen, and oxide level of the liquid metal; ferrous examples were stainless and various ferritic steels.

The corrosion resistance of some materials in sodium and lithium V. S. Lyashenko and V. V. Zotov (*A/CONF.15/P/2194*, pp.28; from *Nucl. Sci. Abs.*, 1959, **13**, April 30, 913) The corrosion of steels in a flow of Na contaminated with O_2 is studied; the erosion resistance of cylindrical samples of steels and Ni heated in Na is investigated, and the results of corrosion studies of some steels and pure metals in Li under static conditions are presented and discussed.

Anodic corrosion of nickel–cobalt and nickel–iron alloys in pyrophosphate plating solution V. Sree and T. L. Rama Char (*Corros. Prev.*, 1960, **7**, April, 41–45) Anode efficiency and potential are explored to assess the use of cast Ni–Co and Ni–Fe anodes for the plating of bright deposits from pyrophosphate solutions. Metals must be present in the solutions as chlorides.—J.W.J.

Interim report on the corrosion of aluminium and stainless steel by Turco 4306–B cleaner D. Griggs (*HW–53333*, pp.4; from *US Res. Rep.*, 1959, **31**, May 15, 377) No abstract.

Corrosion of carbon steel in waste solutions containing mercury P. M. Kranzlein (*DP–416*, 1959, Nov., pp.12; from *Nucl. Sci. Abs.*, 1960, **14**, May 15, 1102) The corrosion behaviour of A–285, A–135, A–106, and A–53 carbon steels was studied in multicomponent waste solutions containing Hg. In the liquid phase, corrosion was at a very low rate, and Hg did not increase it. In the vapour phase and at the vapour-liquid interface, pitting occurred, independently of solution composition, caused mainly by condensation of oxygenated water from aqueous wastes.—S.H.-S.

Practical experience with the foil method for shop control of salt baths, based on determination of carbon content K. Winterer (*Durferrit-Hausmitteilung*, 1951, (24), 7–17; *HB–4307*, 1958, Nov.; from *US Tech. Trans.*, 1959, **1**, June 5, 380).

The effect of metal species present in irradiated fuel elements on the corrosion of stainless steel in nitric acid A. B. McIntosh and T. E. Evans (*A/CONF.15/P/30*, pp.21; from *Nucl. Sci. Abs.*, 1959, **13**, April 30, 901) Presence in soln. of oxidized members of redox couples leads to accelerated attack of stainless steel by HNO_3. This can cause accelerated corrosion in irradiated fuel elements, which are sometimes dissolved in HNO_3 during processing. The mechanism of corrosion in boiling HNO_3 and the influence of the oxidizing species are discussed.

Photometric procedures for the analysis of nuclear reactor corrosion products J. R. Ciaranello and K. E. Combs (*KAPL–M–JRC–2*, 1959, Dec., pp.25; from *Nucl. Sci. Abs.*, 1960, **14**, May 15, 1072) An evaluation of photometric procedures is presented. Standard methods were adopted and analytical procedures were tested with synthetic samples of known composition and found to give acceptable results. Methods were also applied to analysis of corrosion products taken from non-radioactive systems.—S.H.-S.

Corrosion by solutions containing HNO_3, HF, and reducing agents M. La V. Holzworth (*DP–284*, 1958, May, pp.24; from *Nucl. Sci. Abs.*, 1958, **12**, Nov. 30, 2037) Corrosion of stainless steel is markedly increased by NH_2OH, HNO_2, or sulphamic acid but not by ascorbic acid. Some types of steel are much less corroded in the presence of small concentrations of Al or Ag ions and 309 Cb is protected by cupric or ferric ions.

Additional tests on the corrosion of carbon steel following the Turco–4512 decontamination process A. P. Larrick (*HW–62690*, 1959, Nov., pp.9; from *Nucl. Sci. Abs.*, 1960, **4**, Sept. 15, 2159) Carbon steel, 304 stainless steel, and Zircaloy-2 coupons were treated in Turco-4512-2b-inhibited H_3PO_4 decontaminating solution and then charged in a pH 10, 290°C recirculating water loop. The decontaminating

solution pretreatment did not affect the corrosion behaviour of 304 s/s or Zircaloy-2 but did increase the carbon steel initial penetrations by a factor of 2 and the corrosion product film weights by a factor of 1·7 over those of the non-treated carbon steel coupons. The corrosion rate of the carbon steel coupons was not increased by the decontaminating solution pretreatment.—C.F.C.

Rust prevention: an effective compromise (*Ind. Fin.*, 1960, **12**, Nov., 41) Corrosion Prevention Ltd have developed a rust-proofing liquid containing a metal, known as 'Anogal', which is an effective compromise between conventional paints and anodic metal coatings. The properties of the coating are briefly outlined.—G.F.

Rust preventives tested for staining qualities (*Steel*, 1960, **147**, Aug. 1, 92) A method developed by Republic Steel Corp. researchers, to permit rust-proofing agents to be evaluated in the laboratory, rather than in the field where testing costs are higher, is reported.

New chemical inhibits atmospheric corrosion F. Dreher (*Steel*, 1960, **147**, Aug. 22, 85) A transparent oil-base thixotropic fluid called RP252, that gels on contact with metal, is used as an inhibitor for spraying American Motors' Rambler underbodies to prevent rusting during shipment in open railway cars and outdoor storage, for an output of 1200–1600 underbodies daily. Simplicity of application and ease of removal are claimed.—S.H.-S.

Determination of inhibitor film persistence J. A. Knox and R. Stout (*Corrosion*, 1959, **15**, Oct., 554t–556t) The authors describe a simple screening test for evaluating the durability of protective inhibitor films formed by relatively high inhibitor concentrations. Results are presented comparing different inhibitors.—G.F.

Corrosion inhibitor evaluation from cathodic polarization measurements R. A. Legault and N. Hackerman (*Corrosion*, 1959, **15**, Oct., 517t–522t) The authors describe a method for providing a rapid and relatively accurate means of evaluating the efficiency of corrosion inhibitors in systems which are in pH ranges of commercial interest.—G.F.

Tests for the protective action of volatile inhibiters on long service life parts Lekareva (*RTS No.*1132, *SLA* 60-13462; from *Vsesoyuznoye Nauchnotekhnicheskiye Soveshchanige po Korrozii i Zashchite Metallov*, 1958, May, 19–24; Moscow, 9–10, from *US Techn. Trans.*, 1960, **4**, July 27, 118) The use of aqueous solutions of dicyclohexylammonium nitrate for inhibition with paper proved to be advantageous. Supplementary greasing of cast iron parts prior to conservation by the inhibitor was not helpful.

Sodium vanadate as a corrosion inhibitor for monoethanolamine (*Corros. Prev.*, 1960, **7**, May, ii–iii) A description is given of the rise of sodium vanadate to control corrosion in CO_2 removal units at Michigan Seamless Tube Co.

Vapour-phase inhibition of atmospheric corrosion S. E. Sexton (*Corros. Techn.*, 1960, **16**, May, 147–150, 162) The nature, action, and applications of these inhibitors are outlined, especially dicyclohexylammonium nitrite.

Metallic corrosion inhibitors I. N. Putilova, S. A. Balezin, and V. P. Barannik (1960, pp.196; from *US Tech. Trans.*, 1960, **4**, Sept.14, 259) No abstract.

Corrosion protection of steel structures (*Draht*, 1960, **11**, May, 249) A brief outline of methods of cathodic protection of conduits, tanks, etc.

Shot peening for protection against stress corrosion cracking H. Suss (*KAPL–M–HOS–9*, 1959, Sept., pp.15; from *US Res. Rep.*, 1960, **34**, July 15, 106) No abstract.—S.H.-S.

Treatment of water with hydrazine to prevent metal corrosion in steam boilers P. A. Akol'zin and N. M. Mikhailova (*Teploenergetika*, 1960, (7), 59–64) Water treatment with hydrazine is the best method for removing residual oxygen from the deaerated water of a power station. The treatment uses hydrazine hydrate and sulphate. The latter may replace completely the toxic hydrate. The rate of reduction between hydrazine and O_2 increases with temp. and with an increase in the pH to a maximum (9–11). The different impurities in the water speed up the reaction.

Acid-resistant castings not susceptible to intercrystalline corrosion S. A. Shved (*Metalloved. Term. Obra. Met.*, 1960, (1), 20–24) The presence of chromium ferrite in austenitic acid-resistant steel imparts its resistant properties to intercrystalline corrosion without alloying the metal with Ti. This phenomenon is explained by the migration of chromium and carbon to the boundaries of the α- and γ-phases. In cast components containing 0·15–0·20%Ti there is the possibility of combining the main components (Cr, Ni, Mn) so as to obtain a metal after quenching with 10–25% α-phase, imparting a high resistance to the metal against intercrystalline corrosion. With a Ti content exceeding 0·30%, contamination of the castings with non-metallic inclusions appears and along the grain boundaries dendritic inclusions of titanium sulphides are found.

Protection of nitrided components of stainless steels from corrosion in water L. Ya. Gubich and A. G. Andreeva (*Metalloved. Term. Obra. Met.*, 1960, (1), 10–13) To prevent corrosion of nitrided stainless steels in water it is sufficient to boil them for 1 h in a 10% solution of $K_2Cr_2O_7$. They may also be placed for 1 h in a 10%$K_2Cr_2O_7$ solution at 70° or boiled with subsequent immersion in a 10–15% hydrophobic solution of fluid silicon-organic compound GKZh–94 in benzene. The protection of stainless steels from corrosion in water after the action of kerosene at 100° for 50 h can be achieved by a treatment with a boiling 10% solution of $K_2Cr_2O_7$ with subsequent immersion in a 10–50%GKZh–94 solution in benzene.

Improvement of the corrosion resistance of chromium–nickel coatings H. H. Reinsch (*Met.-Reinigung Vorbeh.*, 1960, **9**, Sept., 155–157) Methods of improving the corrosion resistance of these coatings, and application of the coatings in industry are discussed.

Corrosion prevention. 1. T. H. Turner (*Corros. Prev.*, 1960, **7**, July, 41–44) A brief survey of engineers' materials, including slow-rusting copper-bearing steels, lead, and coated metals, with a list of sources of information on available metals and alloys.—S.H.-S.

Corrosion prevention in oil tankers M. Seo and S. Takeshima (*Corros. Prev.*, 1960, **7**, July, 32–38, 44) A paper, originally presented at the 5th World Petroleum Congress, 1959, reviews the internal corrosion of oil tankers, cathodic protection, performance of zinc anodes, seawater/oil tests, the performance of Al alloy anodes, the effect of 'electro-coating', and the use of inhibitors. A series of tests and their results are presented.—S.H.-S.

Report of the Scientific and Technical Society for water transport: Protection of seagoing vessels from corrosion (*Trudy nauchno-tekhnicheskogo obshchestva vodnogo transporta Zashchita morskikh sudov ot korrozii*, 1958, pp.147) In October 1957 an all-Russian conference took place in Odessa regarding the corrosion of sea-going vessels, and in May 1958 a similar conference was convened in Moscow regarding the corrosion of metals.

V. F. Nergeev and A. M. Kyazimov (9–13) The problem of protecting steel equipment from corrosion by sea-water, the essence of which is to transform the entire submerged surface of the metal into a cathode when corrosion can no longer take place is considered. This is the aim of electro chemical or cathodic protection and is attained by reducing the electrode potential of steel in water by connecting the object to the negative pole of a direct current source, while the positive pole is then connected either to a soluble (steel) or insoluble (graphite) anode. A table is given of rates of corrosion of different steels for time intervals of from 30 to 226 days from which it may be seen that the rate of corrosion decreased appreciably with time, that marine growth reduces the average rate of corrosion but favours the growth of local corrosions, that low alloy steels have no great anticorrosion properties in comparison with carbon steels and that the resistance of copper and other low alloy steels in the atmosphere is explained by anode passivation.

I. Ya. Bogorad (13–22) This paper considers in some detail the effect of scale which has a positive potential greater than that of steel by 0·2–0·3 V and forms a powerful cathode. The scale of low-alloy steels has a high resistance to mechanical and chemical action. Scale on carbon steels may be scraped off with wire brushes. The properties of some protective coatings are listed.

S. A. Ivanov (22–26) The principal cleaning procedures in use are considered such as hammering and scraping devices, which however cause in the end increased corrosion and which are being replaced by sand-blasting which has proved more efficient. Flame and heat-treatment for scale removal are also mentioned as well as the protection of component parts exposed to sea water such as bolts, rudders, the chamfers of propeller-shafts, etc., for which zinc coatings are recommended.

V. I. Sergeev (26–32) The problem of corrosion as it affects vessels for internal navigation and lists the different protective coatings in use is discussed.

N. A. Sokirko (32–34) The corrosion of vessels plying in the Black Sea is outlined, and the types of steel plates and the type and degree of corrosion discovered are reported.

K. G. Nikolaev, V. A. Klimova, and K. I. Lebedeva (34–39) Task of increasing the resistance of welded joints is considered and a whole range of suitable chemical compositions for the weld metal is given.

S. I. Leznov (39–40) Passivation tests at Kerson made with solutions of phosphoric acid, ethyl alcohol, and water in different proportions are reported.

V. A. Kuznetsov (41–42) Experiences with the cleaning of plates below the water-line by means of ultrasonics generated by a hydraulic ultrasonic frequency wave generator are described. The paper also mentions other protective methods such as phosphatizing with P_2O_5 which is generated as an aerosol by the combustion of red phosphorus, also other chemical compounds for combating scale formation such as phosphoric acid, film-forming materials, catalysts, surface-active components, inhibitors, thickening agents, and solvents; also organic protective coatings and bituminous compounds etc.

T. L. Danilov (43–45) The corrosion of copper pipes in the Black Sea.

V. I. Sergeev (46–48) An instrument for measuring the penetration of the corrosion layer is described.

V. N. Elizarov (48–51) Some coatings acting as protections against corrosion and overgrowths are described.

E. V. Iskra (52–58) The compositions of a few anti-corrosion paints are given.

V. A. Bershtein (58–62) Some non-metallic paints are reported on.

I. A. Boev (62–63) Experiences of a tanker captain with different protective coatings are described.

M. N. El'kind (64–67) A condensed account is given of the various methods of cleaning eroded and overgrown ship plates.

I. I. Marin (67–75) A method of electrolytic cleaning of ships' bottoms from scale and paints is explained.

V. V. Krasnoyarskii (75–78) An electrochemical method of protection against corrosion is based on the fact that when electrolytic production of oxygen takes place on the surface of the metal, hydroxyl ion accumulates within the diffusion layer together with the undischarged cations (Ca^{++}, Mg^{++}, Na^{++}, etc.). In the absence of agitation the hydroxyl ions form in the excess of cations and produce a positive charge. The electrical field prevents the exit of the colloidal particles from the diffusion layer and promotes their thickening and attachment to the metal.

M. Ya. Zaslavskii (78–82) A method of hydraulic sandblasting is noted.

V. V. Troshenin (82–85) Mechanization in the docks.

M. M. Drakovskii and F. K. Yasyr (85–89) Some mechanical devices for the mechanization of cleaning the under-water portions of the hulls are shown.

I. V. Bel'chev (89–90) The cleaning and painting of the hulls during construction are discussed.

I. I. Khain (91–93) Cold phosphatizing of the under-water portion of the hull of sea-going vessels is described.

V. V. Krasnoyarskii (93–96) The electrolytic

phosphatizing of steel as a means of preparing the surface to take the protective coatings is described, and tests are reported at 18–20° with three solutions, all containing H_3PO_4 in various proportions and also ZnO, $NaNO_2$, HNO_3,$KClO_3$, NaF with a current strength of between 0·5–1·10 amp. A diagram is shown of a simple arrangement consisting chiefly of a perforated spreader connected to the solution by a flexible tube and also joined to the positive terminal. This is passed over the metal surface which is connected to the negative terminal.

A. A. Farkhadov (97–101) Cathodic protection of sea-going vessels is reviewed and the advantages of the suggested installation are listed, such as the high efficiency and great economy in material and current. Standard sources of current may be used and there are also the simplicity of application and the possibility of using the method with currents of low densities.

Yu. E. Zobachev (101–109) The protection of internal surfaces of tankers from the point of view of structural changes and the use of corrosion resisting materials is discussed, protectice coatings on the internal surfaces, humidity control, inhibitors in the load or in the sea-water ballast, washing the internal surfaces with inhibitors, cathode protection, etc., are included.

I. I. Frantsevich, A. F. Zhurakhouskii and E. L. Pechentkovskii (110–117) The use of protecting alloys on a zinc and an aluminium base, containing calcium, for which an increase in the service life by a factor of 10–12 is claimed, is remarked on.

I. I. Zenova (117–120) The planning of the protective coating on vessels is discussed.

(121–125) Discussion of the protection of internal surfaces of oil tankers, corrosion strength of SKhL–1 steel, improving quality control of steel for naval constructions, studying the causes for increased corrosion in tankers produced in series, the use of high resistant steel, comparative data for the corrosion of vessels, coordination and extension of the study of corrosion in vessels, improvement of the methods of cleaning and preparing the surfaces for the application of protective coatings, centralization of the manufacture of protective materials, and scheme for lead–red-lead coatings.

(126–127) Recommendations of the conference based on the above mentioned proceedings are set out.

(128–137) A summary of the protective possibilities of the underwater portion of the hulls of sea-going vessels is appended.

(138–145) A reference list (Russian and foreign sources), specifications for MVH–52–57 standards for protective work, and a list of publications covering this subject in some detail are contained.

The protection of metals. III. Cathodic protection applied to ships and other metal structures immersed in sea-water and rivers. Experiences with metal landing-stage plates M. Serra and J. J. Royuela (*Rev. Cien. Apl.*, 1960, **14,** Sept.–Oct., 422–428) The results of corrosion tests on metal landing-stage plates are reported. The plates were tested in pairs, one used as a standard, the other was cathodically protected by means of an impressed current. The tests ran for the order of 200 days and waters from the ports of Bilbao, Pasajeo, El Ferrol del Caudillo, Vigo, Sevilla, Cartagena, and Valencia were used. Losses in weight, current densities, and potentials were measured.—P.S.

The 'Toxion' system. A new anti-fouling treatment for ships F. A. Hughes & Co. (*Corr. Prev.*, 1960, **7,** March, 49–54) A system toxic to all types of marine fouling organisms including weed is described, using a highly toxic non-persistent poison dissolved in a non-water soluble liquid vehicle and discharged by compressed air through small pipes fitted in selected position on the outside of the hull. An electric field is created by applying current which gives cathodic protection, and poison, rising in the form of bubbles, is attracted to the hull. Details of the system, its chief advantages, approximate costs, estimated savings, and service experience are presented and discussed.

ANALYSIS

The use of polarization potential titration in the iron- and steelworks laboratory K. Abresch and E. Büchel (*Arch. Eisenh.*, 1960, **31,** Oct., 595–601) The application of this volumetric method, in which the end point is indicated by galvanostatically polarized electrodes, to the determination of Cr, V, As, and Mn and other ions is described (12 refs).

On an automatic polarization potential titration with A.C. P. Dickens and P. König (*Arch. Eisenh.*, 1960, **31,** Oct., 603–606) A complexometric titration was carried out automatically, the method being based on changes in polarization resistance. The equipment and examples of its use are described.

Chemical methods of analysis. Report by Committee E–3 (*ASTM Preprint* 52, 1960, pp.45) The report includes tentative methods for the chemical analysis of ferro-boron for B, Al, Si, and C; electronic Ni for Cu, W, and Mg; hydrogen loss in Cu powder; Cu in steel, cast, OH, and wrought iron; Ti and Ti-base alloys for Al, Mg, Si, and W; revision of tentative recommended practice for photometric methods of chemical analysis of metals; proposed revision of recommended practice for apparatus and reagents for chemical analysis of metals.—J.W.T.

Combined method of analysis for high-alloy iron and steel W. B. Sobers (*Foundry*, 1960, **88,** Sept., 110–113) A procedure is described which will serve to analyse for seven elements, Si, Mn, P, Cr, Ni, Mo, and Cu, using a single sample and dilution techniques. For a combination of speed and accuracy, colorimetric, gravimetric, and volumetric methods are used. Solutions used in making analyses are tabulated and the treatment for each element is given in detail.—S.H.-S.

Review: 'The determination of gases in metals' C. J. Smithells (*JISI*, 1961, **198,** June 124–125) [This issue].

Gas chromatographic determination of the hydrogen in cast iron J. Kashima and T. Yamazaki (*Imono*, 1960, **32,** July, 497–501) A cast iron sample was set in a quartz tube and heated, A being passed through the tube at a constant flow rate and then conducted to the gas chromatographic analyser when the H_2 content of the gas was measured for each elapsed time unit. Results were interpreted by plannimeter and the total H_2 content obtained. Conditions of measurement are detailed.

Determination of hydrogen, oxygen and nitrogen in metals by melting under reducing conditions in an argon atmosphere J. Hancart and J. Marot (*Rev. Mét.*, 1960, **57,** Oct., 911–917) The method is described, and results are reported showing good agreement with those obtained by vacuum fusion for O_2 and N_2; simultaneous determination of H_2 is being investigated, but this presents difficulties.

The determination of nitrogen in steels, cast irons and ferroalloys J. Calmettes and H. Guinot (*Rev. Mét.*, 1960, **57,** Oct., 925–933) It is shown that there is at present no method generally applicable to the determination of total N_2 in ferrous materials. Some limitations of available methods are discussed.

Gases in ferroalloys R. Limpach and B. Marincek (*Arch. Eisenh.*, 1960, **31,** Nov., 639–643) The determination of the gas content of ferroalloys by vacuum fusion is described, in apparatus working at up to 2000°C, and the results are discussed.

Gas contents and form in which the gases are combined in ferroalloys A. Fuchs and J. Niebuhr (*Arch. Eisenh.*, 1960, **31,** Nov., 645–649) Apparatus for determination of gases in ferroalloys is described, and the H_2 and O_2 contents of various alloys reported and discussed. The form of combination of O_2 and N_2 in ferrochrome is described.

Application of chromatography to the analysis of gas mixtures extracted from metals by vacuum fusion under reducing conditions C. Baqué and L. Champiex (*Rev. Mét.*, 1960, **57,** Oct., 919–923) The reproducibility, sensitivity, and accuracy of the method are examined. Its main advantages are rapidity and accuracy; H_2, CO, and N_2 are separated satisfactorily by a column with a 'Linde molecular sieve'.

Tightening up the method of determining small quantities of carbon in alloys containing chromium V. Kravchenko and V. Nikolaev (*Stal'*, 1960, (12), 1107) A note from Zaporozhe. Fluxing agents were tested at a range of temperatures. Wood's metal at 1370–1380° was best.

EDTA titration of total iron in iron (II) and iron (III) mixtures C. A. Lucchesi and C. F. Hirn (*Anal. Chem.*, 1960, **32,** Aug., 1191–1193) An (ethylenedinitrilo)tetraacetic acid (EDTA) titrimetric method for the determination of both iron (II) and iron (III) gives results in close agreement with those obtained by the Zimmermann-Reinhardt permanganate method. An aqueous solution containing about 10 mg of iron is diluted with alcohol and the pH is adjusted to 2 or lower. Excess EDTA is added and the solution is neutralized: then buffer and Eriochrome Black T are added, and the unchelated EDTA is back-titrated immediately with zinc. The titration must be carried out in a solution of at least 50% alcohol to prevent indicator blocking. The accuracy of the method as estimated from the overall bias of 18 determinations is $+0{\cdot}002 \pm 0{\cdot}02$ mg where 0·02 mg is the standard deviation of the bias. The precision, as estimated from the total standard deviation, is 0·082 mg. The method has been applied to the determination of iron in iron driers.—S.H.-S.

Volumetric determination of iron and titanium. Applications to ilmenites Blanchet and L. Malaprade (*Chim. Anal.*, 1960, **42,** Dec., 603–607) Ferric ions are determined after reduction to ferrous by an excess of $TiCl_3$ in the presence of arsenic-luteotungstic acid, and indicator which forthwith allows reoxidation of the excess of $TiCl_3$ alone. Ferrous ion is then titrated by a classical method. The Ti, brought to Ti^{3+}, is titrated with Ce^{4+} or $Cr_2O_7^{2-}$, in the presence of the same indicator. The method is effective in the presence of ferrous ion, this last being then determined in its turn. The method has been applied to ilmenites.

Determination of nickel and cobalt with 2-(2-hydroxy-5-methoxybenzeneazo)-4-methylthiazole as an analytical agent T. Yanagihara, N. Matano, and A. Kawase (*Trans. Nat. Res. Inst. Met.*, 1960, **2,** (1), 60–62) This reagent forms blue chelate compounds with Ni and Co in the range pH7 to 9, and they are slightly soluble in water. The existence of only a 1 to 2 chelate compound is verified by Job's continuous variation method and a slope ratio method. The *iso*amyl alcoholic solution of chelate shows maximum absorptions at 620 mμ for Ni and 607 mμ for Co, which are suitable for spectrophotometric determination of traces of these metals. The sensitivity is 0·0014γ Ni/cm² and 0·0018γ Co/cm².—S.H.-S.

The determination of small amounts of cobalt in highly alloyed metals R. C. Rooney (*Metallurgia*, 1960, **62,** Oct., 175–180) The method previously described for the determination of small amounts of Co in cast iron (*ibid.*, 1958, **58,** 205–208) has been extended to the analysis of highly alloyed materials, ferroalloys, etc. Interfering elements are extensively investigated.

Methods for the determination of some trace elements in cast iron R. C. Rooney (*BCIRA J.*, 1960, **8,** Sept., 703–716) Procedure developed by the author for the determination of traces of Sb, Bi, Pb, Al, and Co, together with minor modifications made in the light of experience gained during routine use of these methods are described. The essential differences in techniques required for trace analysis, as distinct from normal control analysis, are discussed and the costs of both types of analysis are compared.—S.H.-S.

Separation and determination of small quantities of aluminium in steel B. B. Bendigo and R. K. Bell (*N.B.S. J. Res.*, 1960, **64A,** May–June, 235–238) Iron is removed electrolytically and Al, Ti, and residual Fe with $CHCl_3$ and cupferron at pH 3·5. Al is determined photometrically with aluminon.

1959 Supplement to the bibliography of spectrophotometric methods of analysis for inorganic ions M. G. Mellon and D. D. Bly (*ASTM STP*, 125–A, 1959, pp.27).

Spectrophotometric determination of iron and copper with methyl-2-pyridyl ketoxime and

their simultaneous determination in mixtures D. K. Banerjea and K. K. Tripathi (*Anal. Chem.*, 1960, **32**, Aug., 1196–1200) Methyl-2-pyridyl ketoxime gives a red-violet colour with iron (II) and a yellowish green colour with Cu (I) in alkaline media, affording a convenient method for determination of these metals by measurement of the absorbances at 525 and 410 mμ, respectively. Cu (II) produces the same colour because of its reduction to Cu (I) by an excess of the reagent. Optimum pH range for development of the iron colour is from 10·5 up (to 6N caustic alkali) and for Cu from 10·0 to 11·7. Colour development is instantaneous in both cases, and at room temp. the colours are stable for over 24 h. Beer's law is obeyed by both systems. Most of the common anions are without effect on both colours and many of the cationic interferences can be effectively masked with tartrate. The method is also applicable for simultaneous determination of iron and Cu in mixtures of varying proportions (1 to 13 to 6 to 1).—S.H.-S.

A contribution to the spectrographic determination of niobium and tantalum in the niobo-tantalites R. Boudergues (*Chim. Anal.*, 1960, **42**, Sept., 421–425) A rapid spectrographic determination of Nb and Ta in the niobo-tantalites is described. The source used is an intermittent arc and a high-dispersion spectrograph is employed. For the determination of Nb a pair of lines is utilized 2590·94Å Nb and 2582·24Å Co: the cobalt is the internal standard. The test operates on mixtures of oxides and the influence of Fe and Ta on the standard Co–Nb curve is studied. For this determination of Ta the pair of lines 2582·24Å Co and 2603·57Å Ta is utilized. The influence of Mg is examined. Limits of accuracy: Nb can be determined at from 5 to 65% in its oxide, and the Ta at from 20 to 60% in oxide of tantalum. Accuracy: for Nb 6%, and for Ta 10%.

Spectrochemical determination of acid-soluble aluminium in low-alloy steels by the rotating-disc method F. G. Howell (*WAL TR* 804/19; *AD*–217440; *PB* 151812, 1959, June, pp.20; from *US Res. Rept.*, 1960, **34**, Sept. 16, 327) A spectrographic method for the determination of acid-soluble Al in low-alloy steels was developed using a solution technique with a rotating graphite disc and a high-voltage alternating current spark. The method is rapid compared to chemical analysis, permitting a considerable saving in time. Of the common alloying elements used in low-alloy steels, only W interferes. The method applies to samples containing 0·02% to 0·25% acid-soluble Al. This range includes most of the samples submitted for analysis.—C.F.C.

A general chemical-spectrographic method for the determination of boron in iron and nickel-base alloys R. F. Anderson (*Applied Spectr.*, 1960, **14**, (5), 123–125) Mercury cathode separation is used and the B is taken up in Cu and compared with a single set of standards. Alloys which are not completely removed by electrolysis (Fe–Ti, Ni–Al, Ni–Mg) are unsuitable.

Preparation of silver crucibles for determination of iron in silicates E. B. Buchanan jun. and H. Diehl (*Anal. Chem.*, 1960, **32**, Aug., 1216) A method of preparing silver crucibles ranging in thickness from 2 to 3 mm is described, inner and outer surfaces being smooth but not polished. Occasionally small blisters appeared when the crucibles were fired but these were not detrimental and were much less frequent than when steady direct current was used for the plating. Apparatus and materials, and plating procedure are described in detail.

Analysis of enamels containing zirconium, antimony, and cobalt J. Debras-Guédon, I. A. Voinovitch, and M. Lancelot (*Chim. Anal.*, 1960, **42**, Sept., 437–447) A report, which is the result of work undertaken by the authors at the Laboratory of the Soc. Français de Ceramique, describes an attempt to find a method as accurate and rational as possible to analyse simultaneously enamels containing a large number of elements such as Zr, Sb, Co, Mn, Sn, Pb, Cr, Cu, Ni, As, etc., along with the ordinary constituents silica and alumina: Si, Al, Fe, Ti, Ca, Mg, Na, K, Li, a method not hitherto described in current world literature. After numerous tests of various analytical schemes, operative methods have been selected and are here described. Studies are envisaged pertaining to Ce, Ag, Sr, Cl, F, S, P, and other elements which might be found in complex ceramic materials such as frits, cermets, enamels, etc. Techniques are discussed and an annex on the simultaneous determination of Ti and V by spectrophotocolorimetry is subjoined.

Azo dyes as indicators for calcium and magnesium H. Diehl and J. Ellingboe (*Anal. Chem.*, 1960, **32**, Aug., 1120–1123) From a study of 26 selected monoazo compounds it is concluded that the minimum structural features necessary for union with Mg and Ca are two hydroxyl groups, *o*- and *o'*-respectively, to the azo group, or alternatively, one *o*-hydroxyl group and one *o'*-carboxyl group. The combining ratio of such compounds with Mg and with Ca is invariably one-to-one in aqueous solution. The formation constant for the Mg compound is always greater than that for the corresponding Ca compound.—S.H.-S.

Indicator for the titration of calcium plus magnesium with ethylene-dinitrilotetraacetate F. Lindstrom and H. Diehl (*Anal. Chem.*, 1960, **32**, Aug., 1123–1127) A new *o*, *o'*-dihydroxyazo indicator 1-(1-hydroxy-4-methyl-2-phenyl-azo)-2-naphthol-4-sulphonic acid, is recommended for the titration of Ca plus Mg with EDTA. The new indicator has the same colour change as Eriochrome Black T, but the colour change is clearer and sharper, and aqueous solutions of the indicator are stable indefinitely. It may be substituted for the older indicator without change in procedure, and has been given the common name of Calmagite.

Rapid method for determining lime, magnesia, and titania in blast-furnace slags and other calcareous materials D. J. Kusler, E. A. Hattmann, G. R. Zellars, and R. H. Jefferson (*US Bur. Mines Rep. Invest.*, 5582, 1960, pp.12) Two rapid methods using EDTA are developed and compared with standard processes. Method A requires 3 h, less than half that needed for current methods, and Method B, less than 2 h if TiO_2 is not required.—J.W.J.

The quantitative spectrochemical analysis of flue dusts, iron ores and similar products H. Nickel (*VDIZ*, 1960, **102**, Sept. 1, 1203) The pulverized specimens are mixed with C-powder, compressed into pellets, and excited by a dc arc under an A atmosphere.

Rapid and precise determination of total sulphur in coal A. C. Bhattacharyya and B. P. Bhaduri (*J. Sci. Ind. Res.*, 1960, **19B**, June, 212–214) A rapid and precise method for determining total sulphur in coal, based on combustion of coal samples (0·1–0·2 g) is described.—S.H.-S.

INDUSTRIAL USES AND APPLICATIONS

Low-alloy steel containing vanadium for railway wagons and structures M. S. Mikhalev and M. I. Gol'dshtein (*Stal'*, 1960, (11), 1026–1029) The properties of three heats of 15GF steel, nominally 0·14–0·7%C, 0·9–1·2%Mn, 0·17–0·37%Si, and 0·04–0·09%V, with the V near the upper limit were measured and indicated the material to be suitable for railway use. The somewhat special conditions of production are pointed out in an editorial note with a query as to whether the required properties could be guaranteed.

Stainless steels in the building and public works industries H. Waisblat (*Mét. Constr. Mécan.*, 1960, **92**, Nov., 961–969) A survey of the physical and mechanical properties of stainless steel, calculation, processing, resistance to buckling, weldability, resistance to corrosion, the use of stainless steel in building construction, with a variety of different classes of examples both practical and decorative.

Steels, irons and various alloys for the prospecting and extraction of petroleum B. de Borde (*Rev. Nickel*, 1959, **25**, (5), 121–126) Drill pipe, pumps, and other equipment used in the extraction of mineral oil and its transport are described.

Factors affecting the efficiency and safety of steel wire ropes W. Anderson (*BHP Techn. Bull.*, 1960, **4**, March, 30–35) Five major properties are distinguished, tensile, fatigue, abrasion, crushing, and distortion and corrosion resistances. Sizes, and constructions are discussed in the light of these.

Selection, heat-treatment and usage of steel for earth moving equipment W. W. Sellers and W. J. Cormack (*W. Scot. ISI*, 1960, (532), pp.37) Certain components are subject to heavy stresses and wear, and in selecting the steel hardenability, fatigue strength, notch-toughness, and economy must be considered. Steel of specified hardenability and notch toughness heat-treated under closely controlled conditions must be used. These factors are considered in relation to the specification, production experience, and application of steels. Typical data are tabulated.—R.S.F.C.

The use of steel in the automobile industry. Observations on the utilization of Brazilian steels R. Gaube (*Bol. ABM*, 1960, **16**, Oct., 767–777) The requirements of automobile steels, and the specifications of those used, are reviewed. Common defects are described. The strict requirements of the industry demand laboratory inspection of all material received.

Materials and process applications in the automotive industry M. F. Garwood (*Met. Prog.*, 1960, **78**, Oct., 115–129) The article deals with recent trends and future prospects in various applications, including pearlitic malleable iron castings, cheaper alloy steels, aluminized valves, powder metallurgy, cold extrusion of steel, welding and corrosion protection.

Defects in National steels for the automobile industry J. B. Hucke and D. E. Neto (*Bol. ABM*, 1960, **16**, Oct., 741–749) The types of defects encountered in steels used in the industry are described in a discussion of the need to improve the quality of these steels. It is concluded that the problem can be solved by the close co-operation of supplier and consumer; a plan of action is suggested.—P.S.

Mechanical- and physical-property data on modified 12 per cent chromium martensitic stainless sheet steels for airframe applications J. G. Hoag, D. B. Roach, and A. M. Hall (*DMIC Mem.* 15; *PB* 161165, 1959, Nov., pp.50) Available data are presented on the mechanical and physical properties of these steels, i.e. modified type 420 stainless steels 12 MoV (US Steel Co.) and 422 (Crucible).

Special steels in Bristol Type 188 (*Iron Steel*, 1960, **33**, Oct., 488–493) A discussion of the temp. conditions in supersonic flight and the selection of suitable steels for the research supersonic aircraft Bristol Type 188. Details of some of the forgings are given.

4137Co—a new steel for rocket motor cases G. K. Bhat (*Met. Prog.*, 1960, **77**, June, 75–79) This steel, essentially a 4100 type with added Co and Si, can be heat-treated to yield strengths of 225 000–235 000 psi, and has good machining, deep-drawing, and welding properties.

Tinned containers for food and technochemical industries P. Ranta (*Tek. Kemian*, 1961, June, 595–598) The raw materials used for the production of tinned containers are discussed, the steels most suited for the manufacture of tinplate are given, and their chemical properties explained. The problems involved in the use of tinned boxes in reference to inside and outside corrosion are cited and various corrosion phenomena are dealt with, the classification of different foods as to their corrosion properties being discussed. It is stated that the use of galvanized plate is growing and that of hot-tinned plate decreasing.

HISTORICAL

Roman domestic ironwork, as illustrated by the Brading, Isle of Wight Villa H. F. Cleere (*Bull. Inst. Archaeology*, 1958, **1**, 55–73, Reprint).

Chain mail C. S. Smith (*Met. Prog.*, 1960, **78**, Oct., 296) Digest of 'Methods of making chain mail (14th to 18th Centuries): a metallographic note' (*Technology and Culture*, 1959, **1**, Winter, 60–67) An examination of 16 pieces of German, Turkish, and Persian manufacture (15th–17th century).

English Bloomeries (1329–1589) R. A. Mott (*JISI*, 1961, **198**, June, 149–161) [This issue].

An interesting example of early technology J. Piaskowski (*Ind. e Indust.*, 1960, **37**, Aug., 138–140, 142, 144, from *JISI*, 1960, March, 336–340) [In Spanish].

Ceramics in the Saugus blast furnace, circa 1650 H. M. Kraner (*Amer. Ceram. Soc. Bull.*, 1960, **39,** July, 354–358) An archaeological reconstruction of the first integrated ironworks (in Saugus, a suburb of Boston, on the Saugus River) is reviewed and its products enumerated and its work analysed and compared with that of a modern blast-furnace.—S.H.-S.

An early electric cell? C. MacK. Jarvis (*JIE Eng.*, 1960, **6,** June, 356–357) A note on articles in the German technical press on suggested evidence of galvanic gold-plating 4500 years ago, based on a pre-Second World War discovery near Baghdad.—S.H.-S.

ECONOMICS AND STATISTICS

The question of indices for volume of production and labour productivity in the iron and steel industry A. E. Zholkevich (*Stal'*, 1960, (12), 1137–1140) An improved accounting practice for estimating costs and efficiency is presented.

The financing of Carron Company R. H. Campbell (*Business History*, 1958, **1,** Dec., 21–34, reprint) Historical.

Obtaining least-cost furnace input mixes by linear programming, and some inventory implications G. I. Gartner (*Management Science Rept. No. MS–1; AD–233226; PB 146836*, 1959, July, pp.77; from *US Res. Rept.*, 1960, **34,** Sept. 13, 327) Many combinations of furnace input materials exist, which will meet a set of given furnace output requirements. The linear programming technique can be used to choose that feasible material combination whose material cost is a minimum. The technique can be used to calculate optimal prescriptions for individual heats, or to determine which materials to buy to stock inventory. While previous work has been done on the individual heat problem, this project is concerned with the 'what to buy' decision. Several possible management policies which concern the extent to which linear programming might be used are described as are the implications of a linear programming base system to economize lot size determination. To justify the use of LP in this application as well as to illustrate several points, a number of problems, hypothetical and real, were solved on the IBM 704.—C.F.-C.

MISCELLANEOUS

Architecture to-day. No.466—Brymbo Steel Works, Wrexham A. T. Edwards (*Financial Times*, 1959, May 1, pp.8–9).

Automatic control in Soviet Industry A. Tustin, A. J. Young, A. Asbury, R. H. Tizard, S. S. Carlisle, and P. H. Hammond (*DSIR pamphlet*, 1959, Sept., pp.64) An account of a visit to the USSR. Seven research institutes, three educational establishments, two computing centres, and four factories were included in the tour. Apparatus seen is briefly described and research in progress is listed. Control of tandem mills (10), machine tools (17), blast-furnaces (25, 30), OH furnaces (26, 28), arc furnaces (29), rolling mills (36), and various gauges and instruments are of direct metallurgical interest.

Electrolytic cobalt in Katanga M. A. Bouchat and J. J. Saquet (*J. Met.*, 1960, **12,** Oct., 802–808) A summary of a paper presented by these authors at the International Symposium on the Extractive Metallurgy of Cu, Ni, and Co in 1960. A description of the processes used for the manufacture of purified Co from the Cu–Co ores mined and concentrated by the Union Minière du Haut-Katanga, with reference to a recently developed modification whereby Co cathodes are obtained sufficiently pure for marketing without further treatment.

Obtaining metallic manganese from granulated silico-manganese V. Kravchenko and V. Nikolaev (*Stal'*, 1960, (12), 1106) A note from Zaporozhe. Granulated material is reduced more readily than crushed.

Cathode deposition of vanadium compounds A. S. Goncharenko and O. A. Suvorova (*Zhurn. Prikl. Khim.*, 1960, **33,** (4), 846–849) The cathode deposits of V compounds may be used for the extraction of V from weakly alkaline aqueous solutions. The use of these solutions permit the use of easily accessible and cheap materials for the apparatus such as iron and steel. Electrolytic deposition may be carried out from simple electrolyte baths without expensive additions. The presence in the solution of alkali carbonates and sulphates affect favourably the yield of deposits, and, since the starting solutions are obtained by leaching out the vanadium ores or slurries, they already contain, along with vanadium, the above-mentioned salts.

Recommendations to prevent accidents during the cutting out of gas mains for repairs and alterations Institute of Gas Engineers (*Trans. Inst. Gas. Eng.*, 1955–56, **105,** 75–83) For use with cast iron and steel mains with pressures not exceeding 50 psi.

J. & L. adds to computer capacity (*Iron Steel Eng.*, 1960, **31,** Oct., 175–176) The use of analogue computers for research into various iron- and steelmaking processes by Jones and Laughlin is reviewed.

Methods of improving working conditions in steelmaking and hot rolling shops Ya. A. Shtromberg (*Stal'*, 1960, (12), 1153–1155) Improved localized ventilation and dust control conditions are suggested.

Ocular splinters of steel, some clinical and metallographic data H. Grönwall (*Acta Ophthalmologia* (reprint), 1959, **37,** 413–466).

BOOK NOTICES

BRITISH IRON AND STEEL RESEARCH ASSOCIATION. '*Research on the Rolling of Strip*'. A Symposium of Selected Papers 1948–1958. 11 × 8½ in, pp.216. Illustrated. 1960, London: The Association. (Price £1 1*s.*)

This book is a collection of selected papers on the mechanics of strip rolling, most of which have appeared since 1948 in the Proceedings of the Institution of Mechanical Engineers or the Journal of The Iron and Steel Institute. With its introduction by W. C. F. Hessenberg, it forms a valuable addition to the literature on this subject following the earlier papers by continental workers and the well-known book by Dr Underwood on the Rolling of Metals. In the field of flat rolling the connexion between plant and product is a particularly intimate one. It is the application of scientific principles in both respects which has led to the notable developments of the last two decades.—W. A. JOHNSON.

BUXTON, C. R. and JACKSON, H. S. '*Translation from Russian for Scientists*'. 8¼ × 5¼ in, pp.299. 1960, London and Glasgow: Blackie and Son Ltd. (Price £1 10*s.*)

This book is designed primarily to enable the scientist to acquire an adequate reading knowledge of the Russian language. He is first introduced to the alphabet by means of scientific words that are similar to their English counterparts. The book consists of five sections. The first is concerned with grammar and the second with sentences for translation. The third section consists of annotated texts, and the fourth and fifth sections are devoted to translation passages from various scientific spheres, including many of interest to the metallurgist. This is a useful book, but three minor shortcomings must be mentioned. Not enough practice is given in translating into the Russian, no model translations are included, and the stress of the Russian words is not indicated.—C. I. PEDERSEN.

GRAY, C. S. *et al.* '*Steel Designers' Manual*'. Prepared for the British Steel Producers' Conference in conjunction with the British Iron and Steel Federation. 9½ × 6½ in, pp.vii + 947. Illustrated. 1960, London: Crosby Lockwood and Son Ltd. (Price £2 10*s.*)

The new Steel Designers' Manual is a worthy successor to its forerunner whose comprehensive quality had such wide appeal. Once more there are grouped—between two covers—all the formulae, diagrams, tables, etc. necessary in designing steel frameworks. These are now brought up-to-date, and there is no doubt the simple theory and supporting examples will again prove of substantial benefit to any engineer, architect, or steel user who may consult the volume for answers to his problems.

This second edition of what has rapidly become a standard reference book since its first appearance in 1955, is in accordance with the intention expressed at that time of revising the Manual to incorporate advances in construction techniques. Such developments necessitated the revision of BS.449 which had been the main basis of the examples forming so valuable a part of the book. The 1959 draft of BS.449 entailed drastic alteration of these examples and the accompanying text, but this new edition in no way lowers the standard previously set. In fact the opportunity has been taken of amending other chapters the substance of which has been varied to accord with new or revised British Standards. The information on steel sections has been greatly increased as a result of the new BS.4B which incorporates universal beams and columns. Details of the properties of these sections are now included, as are those of T-bars and Castella sections. A handy supplement is the list of current British Standards relating to steel constructions.—J. R. RICHARDS.

HARRISON, T. R. '*Radiation Pyrometry and its Underlying Principles of Radiant Heat Transfer*'. 9 × 6 in, 1960, New York, London: John Wiley & Sons, Inc. (Price £4 16*s.*)

There is a pressing need for instrumental aids to control high-temperature processes (e.g. steelmaking). Radiation pyrometry can be a powerful tool, provided its limitations as well as capabilities are properly understood. Harrison's book sets out to provide the reader with this kind of understanding. The relevant laws of radiation physics (spectral and geometrical distribution of radiant energy emitted by blackbody and non-blackbody radiators, as well as reflection, absorption, and transmission) are deduced and explained in the first three chapters. The technique of radiation pyrometry is dealt with in chapter 4. Detectors, effect of lens, window, and light guide, ambient temperature compensation, and calibration procedures are discussed. The application of mathematical formulae derived in preceding pages is shown with numerical examples. Photosensitive detectors are only briefly mentioned, though 'it is not unreasonable to expect developments in this field . . . '. Chapter 5 covers the principles and practice of applying corrections for emittance and surrounding wall temperature. Chapter 6 (comprising about one-third of the book) gives tables and graphs needed for design, performance assessment, and calibration. Five appendices (universal constants, an excursion into Maxwell Theory, and the derivation of some equations) round off the volume. The author's declared object of 'providing enough theoretical and practical detail' for engineers operating under a wide variety of conditions, is achieved, though bias is towards the theoretical. Among many graphs and tables there are only a few illustrations and design details; these are largely confined to Brown 'Radiamatic' pyrometers.

Students interested in radiant heat transfer as well as engineers and physicists concerned with radiation pyrometry should find this book very useful, provided they are willing to face the inevitably mathematical treatment of the subject.—G. SYKE.

HUME-ROTHERY, W. '*Atomic Theory for Students of Metallurgy*'. 3rd ed. 8½ × 5½ in, pp.427. Illustrated. 1960, London: Institute of Metals. (Price £2 10*s.*)

This is the third edition of Professor Hume-Rothery's well-known textbook and although it follows in pattern the earlier editions, in detail it is considerably different. The book is written in six sections; parts I to V deal with the general background to the theory of metals and specifically with the free electron and Brillouin theories. Part VI which consists of 127 pages deals with the available data about specific metals, and their interpretation. Professor Hume-

Rothery has maintained throughout this edition the characteristic style which makes his books so eminently readable.

The most notable addition is probably the chapter dealing with the experimental determination of the electronic structure of metals. A very successful attempt is made to explain the potentialities of such complicated techniques as the measurement of the de Haas van Alphen effect, the anomalous skin effect and nuclear magnetic resonance. More conventional techniques such as soft X-ray spectroscopy and the measurement of electronic specific heats are treated in sufficient detail to show their relative importance. There is also a good appendix to the chapter on electronic theories of metallic crystals in which Professor Hume-Rothery leads one through a description of the reciprocal lattice to a clear explanation of extended and reduced Brillouin zones and Jones zones. After reading the book one is left with an impression of the author's great ability in describing modern developments in simple language.

'*Atomic Theory for Students of Metallurgy*' is well produced, well illustrated and very good value for money. It deserves a place on the bookshelves of far more people than the students of metallurgy for whom it was written.—B. B. Argent.

Solov'ev, B. V., Akademiya Nauk SSSR. Institut Mirovoi Ekonomiki i Mezhdunarodnykh Otnoshenii [Academy of Sciences, USSR, Institute of World Economy and International Relations]. '*Chernaya Metallurgiya Anglii*'. ['*The British Iron and Steel Industry*'.] (In Russian). $7\frac{3}{4} \times 5$ in, pp.224. Illustrated. 1960, Moscow: The Academy. (Price 8 r. 20 k.)

This book originates in the Institute of World Economy and International Relations of the Academy of Sciences of the USSR. It deals with the British iron and steel industry mainly from two aspects. Firstly, as a case history of a basic industry under the capitalist system. Secondly, as an industry whose technical advances and shortcomings are of special significance since it is soon to be overtaken by its Soviet counterpart in production per head of population. The period covered is roughly the last 100 years, but mainly that after 1945.

The author sets himself the broad aims of tracing the technical and structural changes which have taken place, discovering why the British share in world iron and steel production has tended to fall, and showing how these factors have been influenced by political and economic considerations. The contents list at the end of this review gives some idea of how he has set about his task.

The sources of information are mainly British and non-communist. Data are presented in 47 tables and there are over 250 numbered references (including some from *Who's Who*).

The general impression of the standard of the British iron and steel industry which the book gives is distinctly unfavourable.

The book, in addition to a short introduction, contains the following chapters. Chapter 1. Brief description of the development of British iron and steel industry during the period of the second stage of the general crisis of the capitalist system ((i) the iron and steel industry in the period of pre-monopolistic capitalism; (ii) the iron and steel industry in the period of monopolistic capitalism before the second world war). Chapter 2. The British iron and steel industry in the period of the second stage of the general crisis of the capitalist system ((i) the nature of the development of the iron and steel industry; (ii) technico-economic characteristics and prospects for development; (iii) sources of raw materials and fuel; (iv) location of iron and steel industry). Chapter 3. The rule of monopolistic capital in the British iron and steel industry ((i) concentration and monopolization of iron and steel production; (ii) the largest monopolies; (iii) British monopolies in international steel cartels; (iv) the growth of state-monopolistic capitalism as exemplified by the iron and steel industry). Chapter 4. Capitalistic utilization of technics and the working class. An appendix contains numerous statistics and there is a final chapter in which the author draws a gloomy picture of the prospects of the British industry.

—S. Klemantaski.

Tinkelpaugh, J. R. and Crandall, W. B. (Editor.) '*Cermets*'. 9×6 in., pp.vi+239. 1960, New York, London: Reinhold Publishing Corp., Chapman and Hall Ltd. (Price £3 16*s*.)

The publishers' statement describes this book as the most thorough survey of oxide and carbide-based cermets ever published. They say that 23 contributors, each a recognized authority in the field, cover the fundamental aspects of forming, processing, testing, and applications, thus giving the reader a complete and accurate account of the subject.

The fact that these 23 contributors have performed this feat in less than 200 pages of text should warn the potential buyer that the book is in fact a superficial introduction to the subject. Nowhere does it give a good account of the fundamental principles involved and in no place is the reader told precisely how to manufacture cermets, or to put them into application. Undoubtedly however, the book will have some value to those who are completely ignorant of the subject, if only for the fact that the bibliographical data provided would assist him in reading further.

Probably the best sections of the book are those provided by C. G. Goetzel on the subject of infiltration, the theoretical introduction by M. Humenik, jun., and T. J. Whalen, and the account of the principles involved in slip casting by B. C. Weber. Most of the other portions of the book are good and reliable but far too short and superficial. The chapter on the preparation of oxides and carbides is completely inadequate—for example the subject of the preparation of carbide is dismissed in less than one page. The section entitled 'A Summary of Good Practice in the Pressing of Cemented Carbides' by J. V. West, is most curious, and in fact it could perhaps more precisely be described as a bad summary of the elementary principles involved.

In the preface it is stated that the contents of the book are limited to American work. At a price of £3 16*s*. it cannot possibly be recommended.—W. D. Jones.

NEW PUBLICATIONS

These titles are also available on index cards in advance of publication in the Journal, *each title being classified under the Universal Decimal system (U.D.C). Details and subscription rates can be obtained from the Secretary, The Iron and Steel Institute.*

Akademiya Nauk SSSR. Institut Metallurgiya im A. A. Baikova. [Academy of Sciences, USSR. A. A. Baikov Institute of Metallurgy.] '*Fiziko-Khimicheskie osnovy proizvodstva stali. Trudy IV Konferentsii*'. ['*Physico-Chemical basis of the production of steel. Transactions of IV Conference*'.] [In Russian.] $10\frac{1}{2} \times 6\frac{3}{4}$ in, pp.420. Illustrated. Moscow, 1960: The Academy. (Price 25 r.)

Akademiya Nauk SSSR. Institut Machinovedeniya. Institut Metallurgiya im A. A. Baikova. [Academy of Sciences, USSR. Institute for the study of Machines. A. A. Baikov Institute of Metallurgy.] '*Obrabotka zharoprochnykh splavov*'. ['*Treatment of heat resistant alloys*'.] [In Russian.] $10\frac{1}{2} \times 7$ in, pp.232. Illustrated. Moscow, 1960: The Academy. (Price 14 r. 75 k.)

Akademiya Nauk SSSR. [Academy of Sciences, USSR.] Chizhevskii, N. P. '*Izbrannye Trudy*'. Tom I. II. ['*Selected Works*'.] Vols.I. II. [In Russian.] $10\frac{1}{2} \times 7$ in, pp.439, 425. Illustrated. Moscow, 1960: The Academy. (Price 26 r. 10 k.; 24 r. 30 k.)

Akademiya Nauk SSSR. Institut Metallurgiya im A. A. Baikova. [Academy of Sciences, USSR. A. A. Baikov Institute of Metallurgy.] Pronov, A. P. '*Kristallizatsiya stal'nogo slitka*'. ['*Solidification of the steel ingot*'.] [In Russian.] $10\frac{1}{2} \times 6\frac{3}{4}$ in, pp.150. Illustrated. Moscow, 1960: The Academy. (Price 9 r. 80 k.)

Akademiya Nauk, SSSR. Institut Fizicheskoi Khimii. [Academy of Sciences, USSR. Institute of Physical Chemistry.] Tomashov, N. D. '*Teoriya korrozii i zashchity metallov*'. ['*Theory of the corrosion and protection of metals*'.] [In Russian.] $10\frac{1}{2} \times 6\frac{3}{4}$ in, pp.592. Illustrated. Moscow, 1959: The Academy. (Price 35 r. 70 k.)

Akademiya Nauk SSSR. Institut Fizicheskoi Khimii. [Academy of Sciences, USSR. Institute of Physical Chemistry.] Vagramyan, A. T. and Sopov'eva, Z. A. '*Metody issledovaniya elektroosazhdeniya metallov*'. Izdanie Vtoroe. ['*Methods of Research on the Electrodeposition of Metals*'. Second edition.] [In Russian.] $8\frac{1}{2} \times 5\frac{3}{4}$ in, pp.448. Illustrated. Moscow, 1960: The Academy. (Price 16 r. 50 k.)

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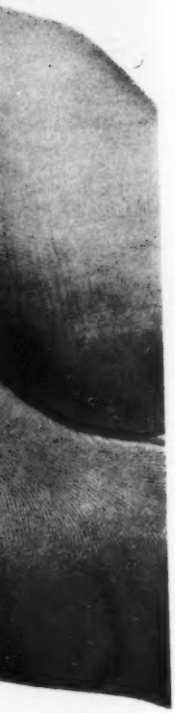

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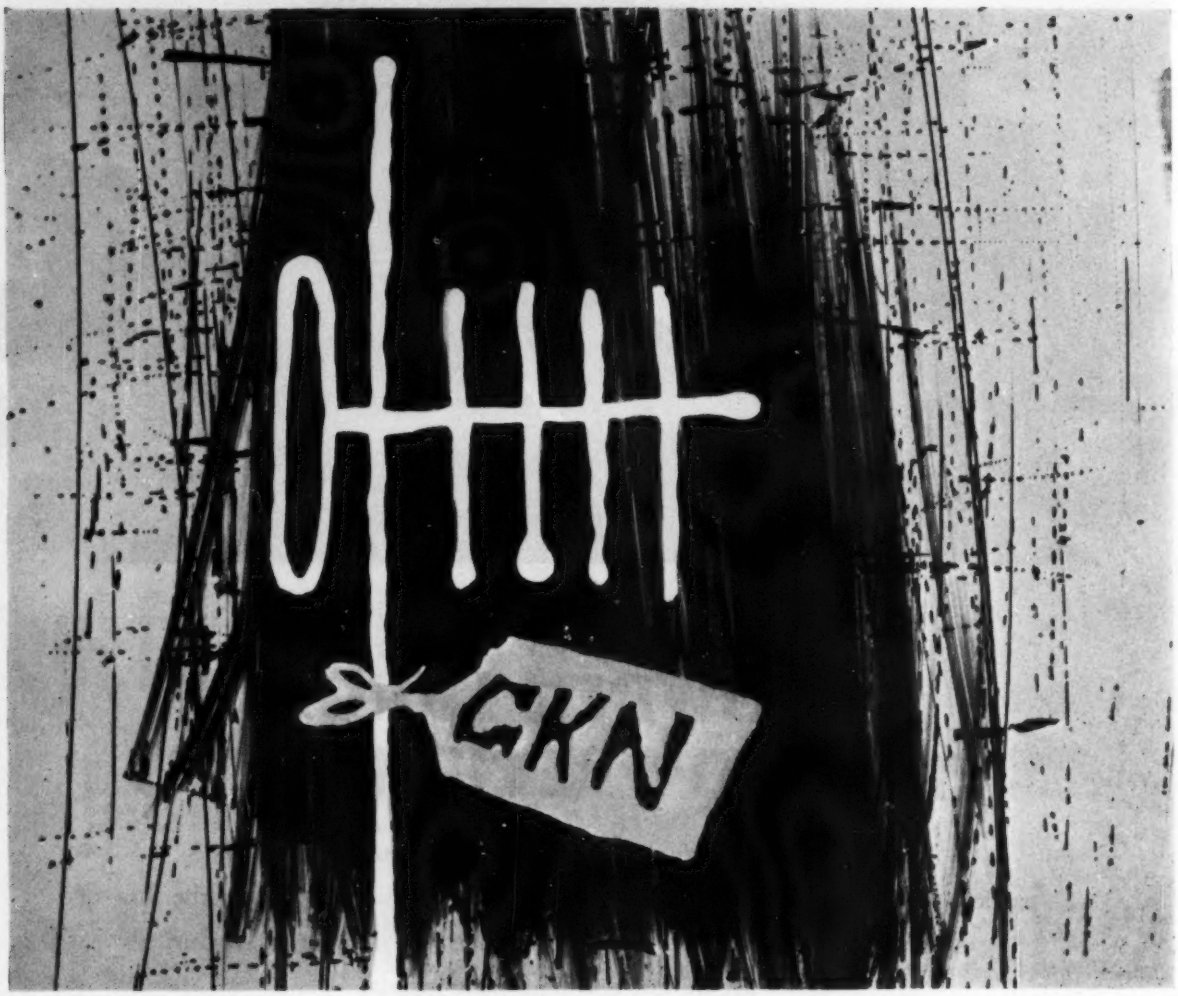

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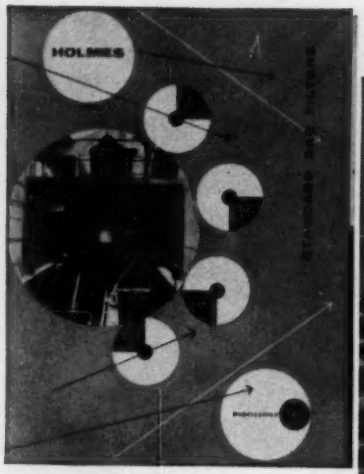

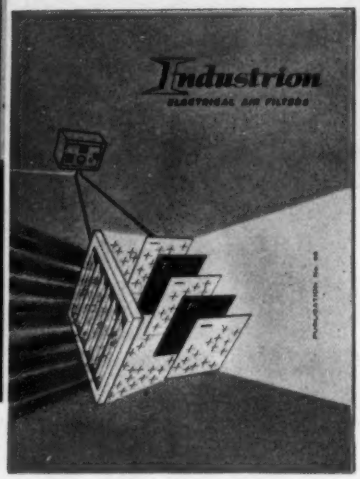

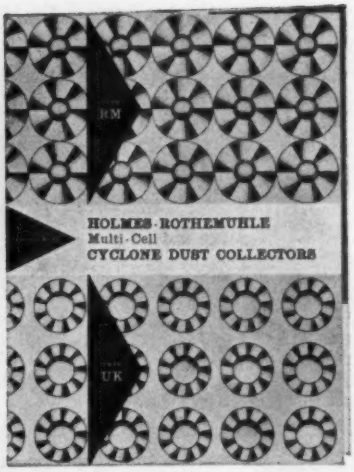

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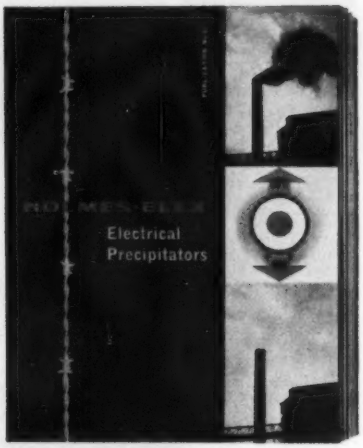

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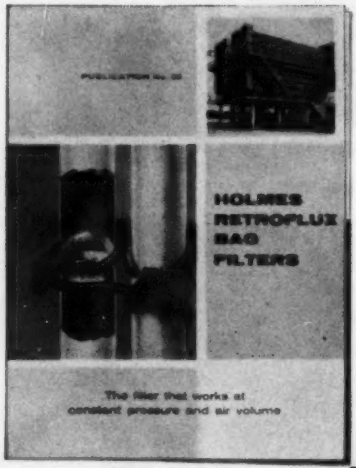

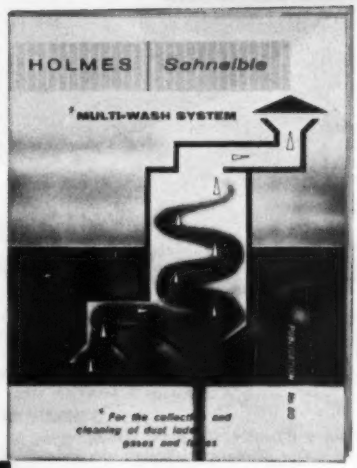

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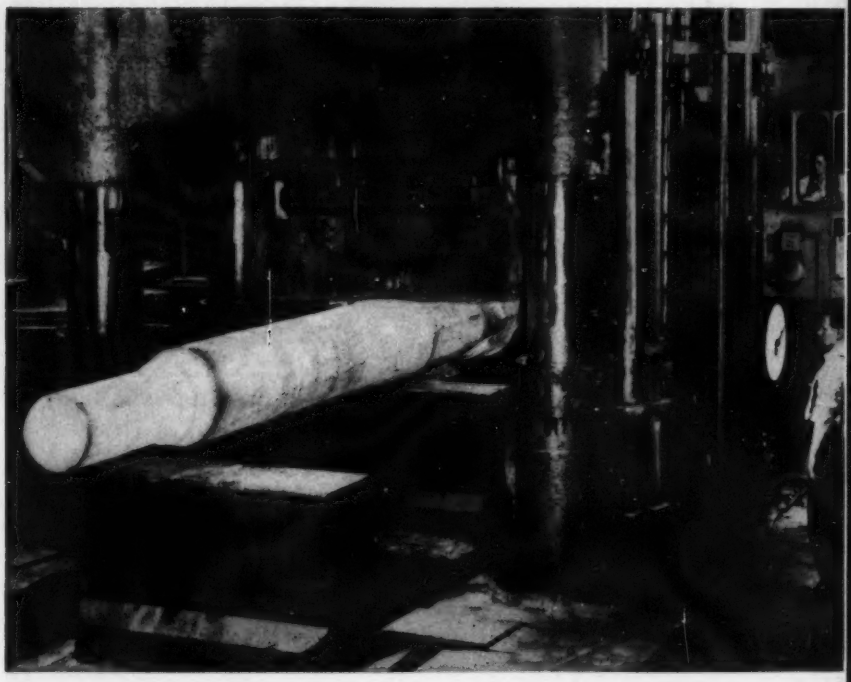

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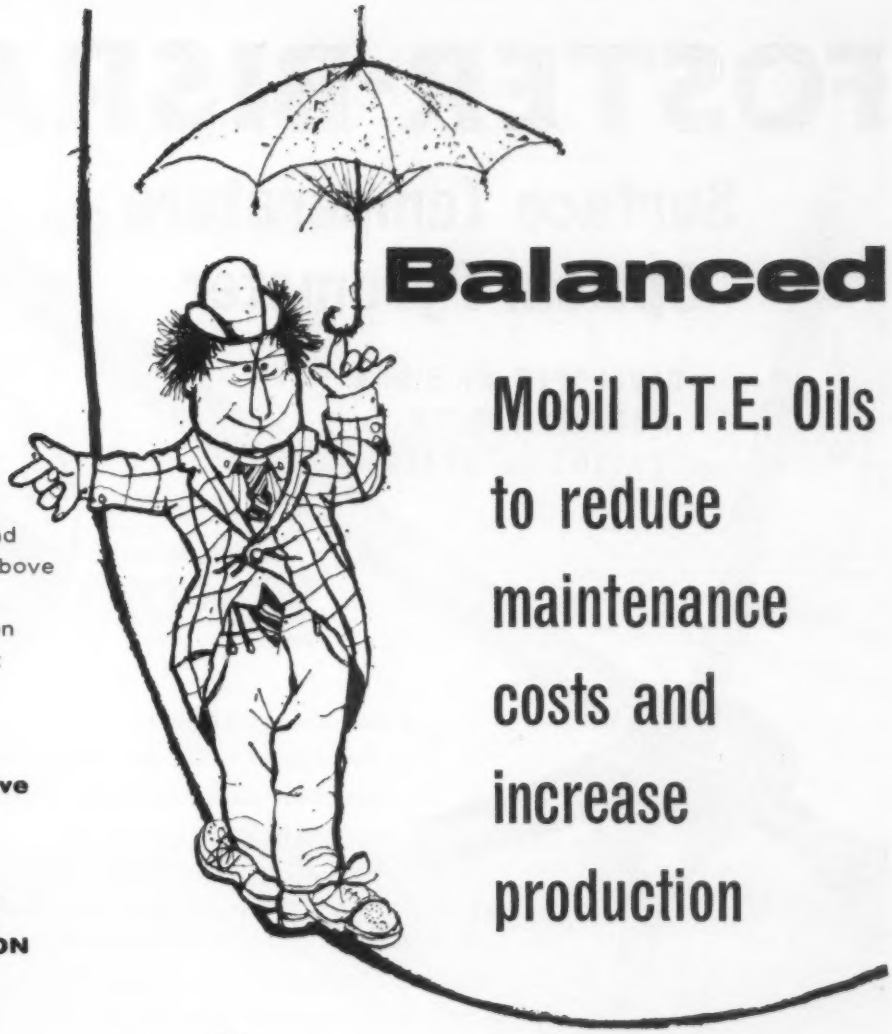

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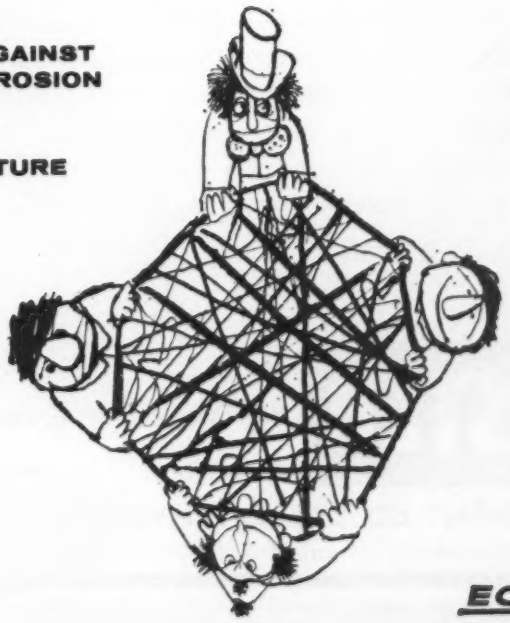

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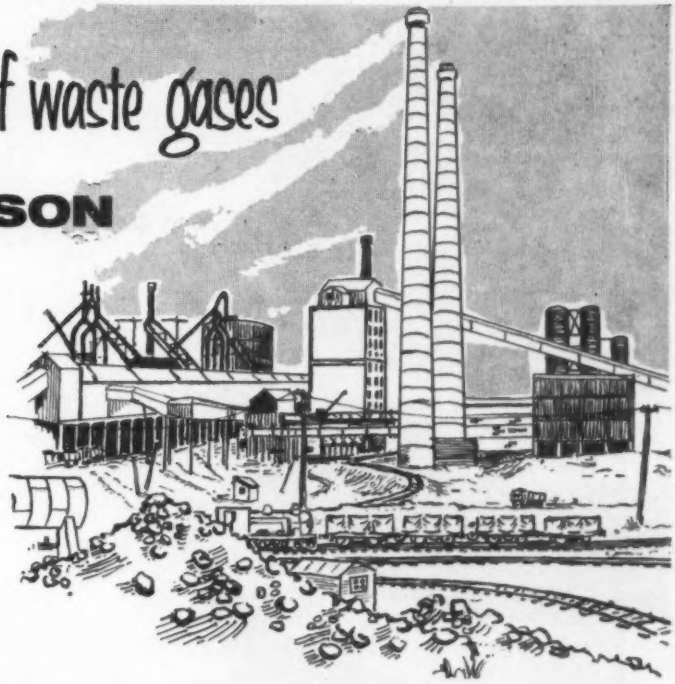
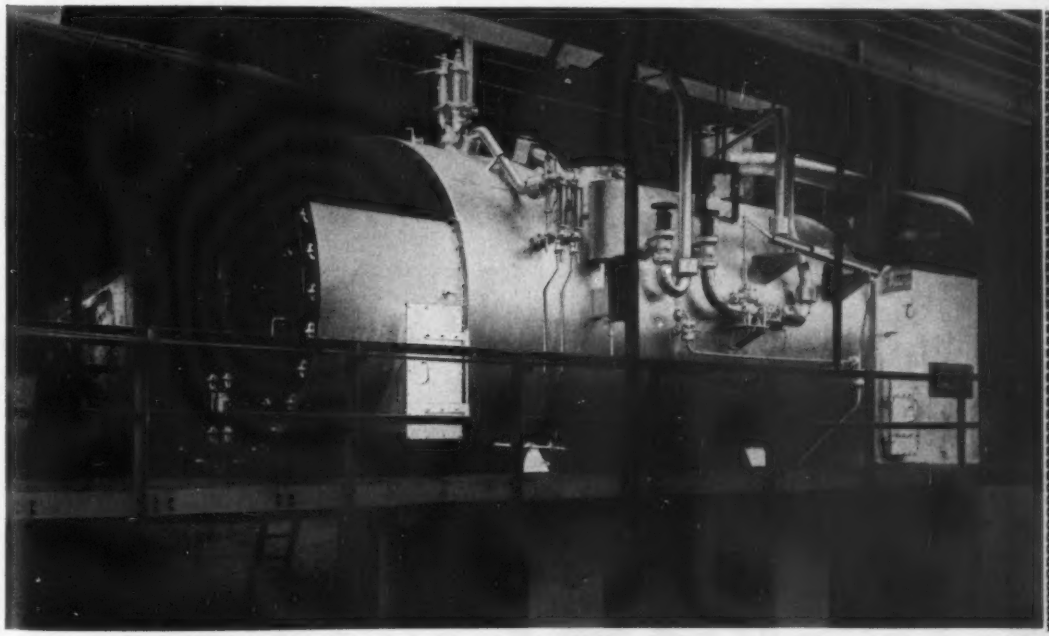
for the efficient use of waste gases

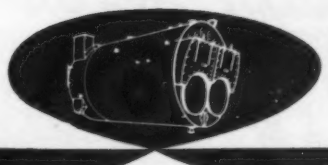
JOSEPH ADAMSON

waste heat boilers



The Joseph Adamson Waste Heat Boiler is designed to make efficient use of the waste gases leaving open-hearth furnaces, reheating furnaces, soaking pits, gas retorts, etc. The straight-through fire tubes have a high ratio of length to bore, giving about 90% tube efficiency and providing a large area of heating surface in a comparatively small space. Brickwork setting is not required and air infiltration is thus avoided. A feature of Joseph Adamson Waste Heat Boilers is that a special cleaning device can be provided in the outlet chamber to allow the tubes to be cleaned while the boiler is at work.





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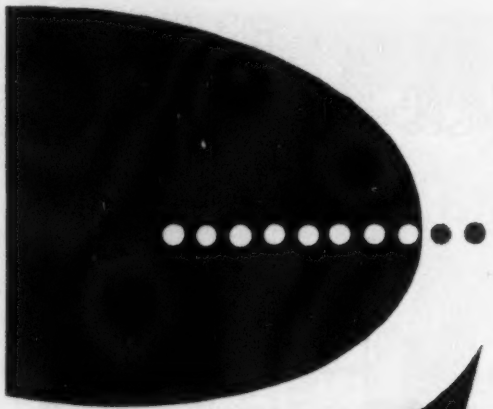

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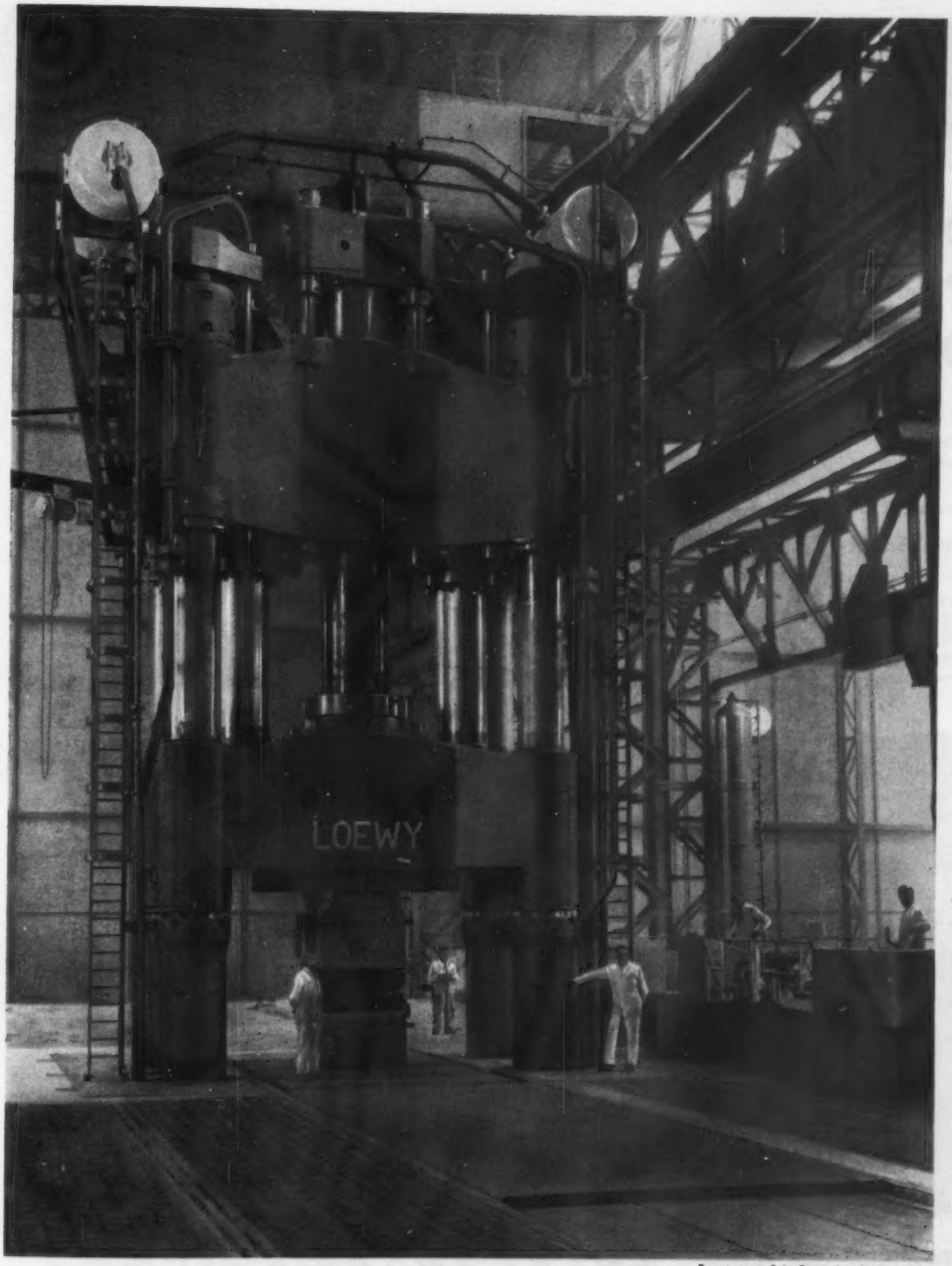

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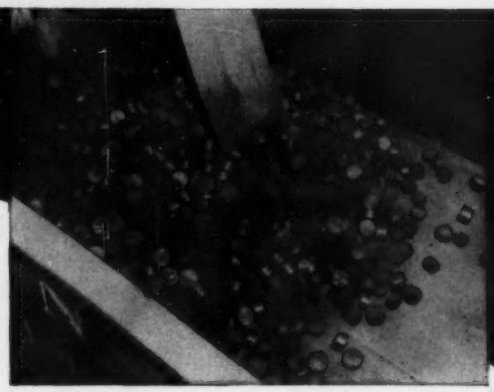

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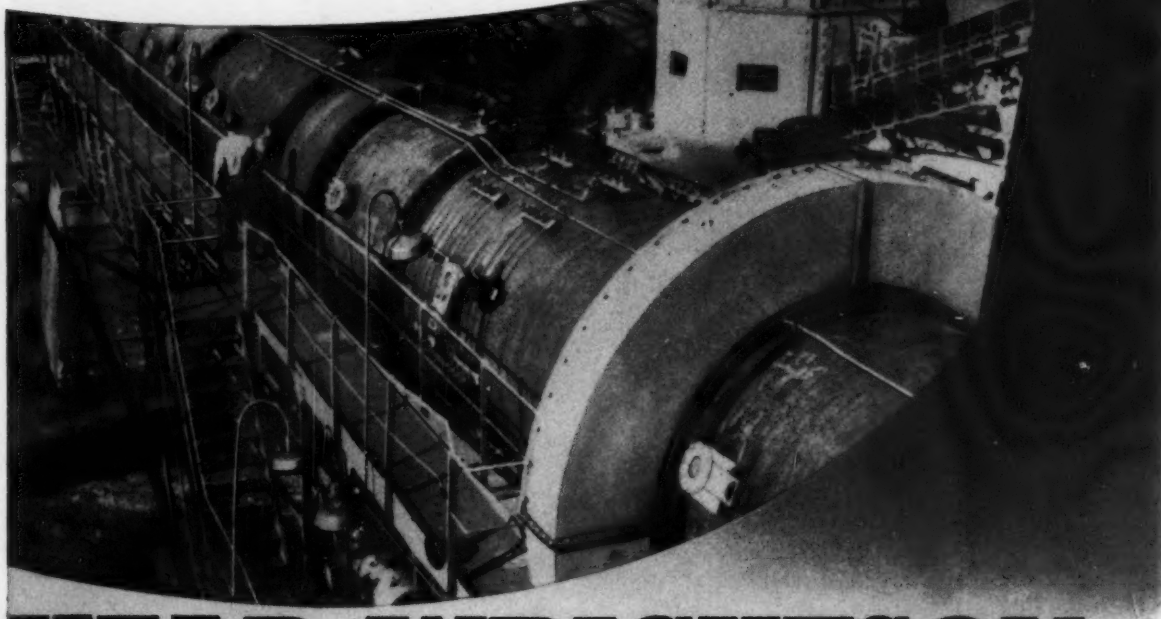

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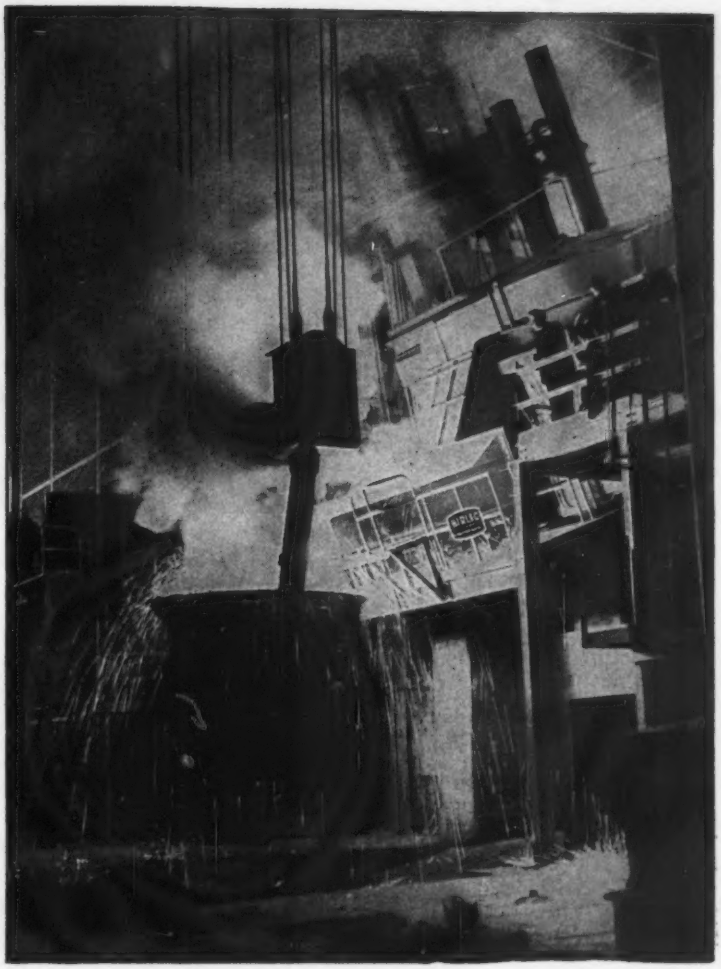

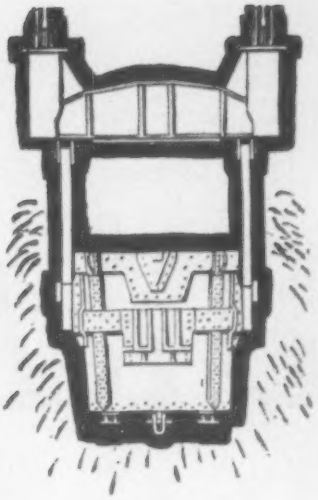

ELECTRIC TONNAGE STEEL

Tapping one of the three electric arc furnaces installed in the new melting shop at Brymbo Steel Works (Branch of GKN Steel Co. Ltd), Wrexham.

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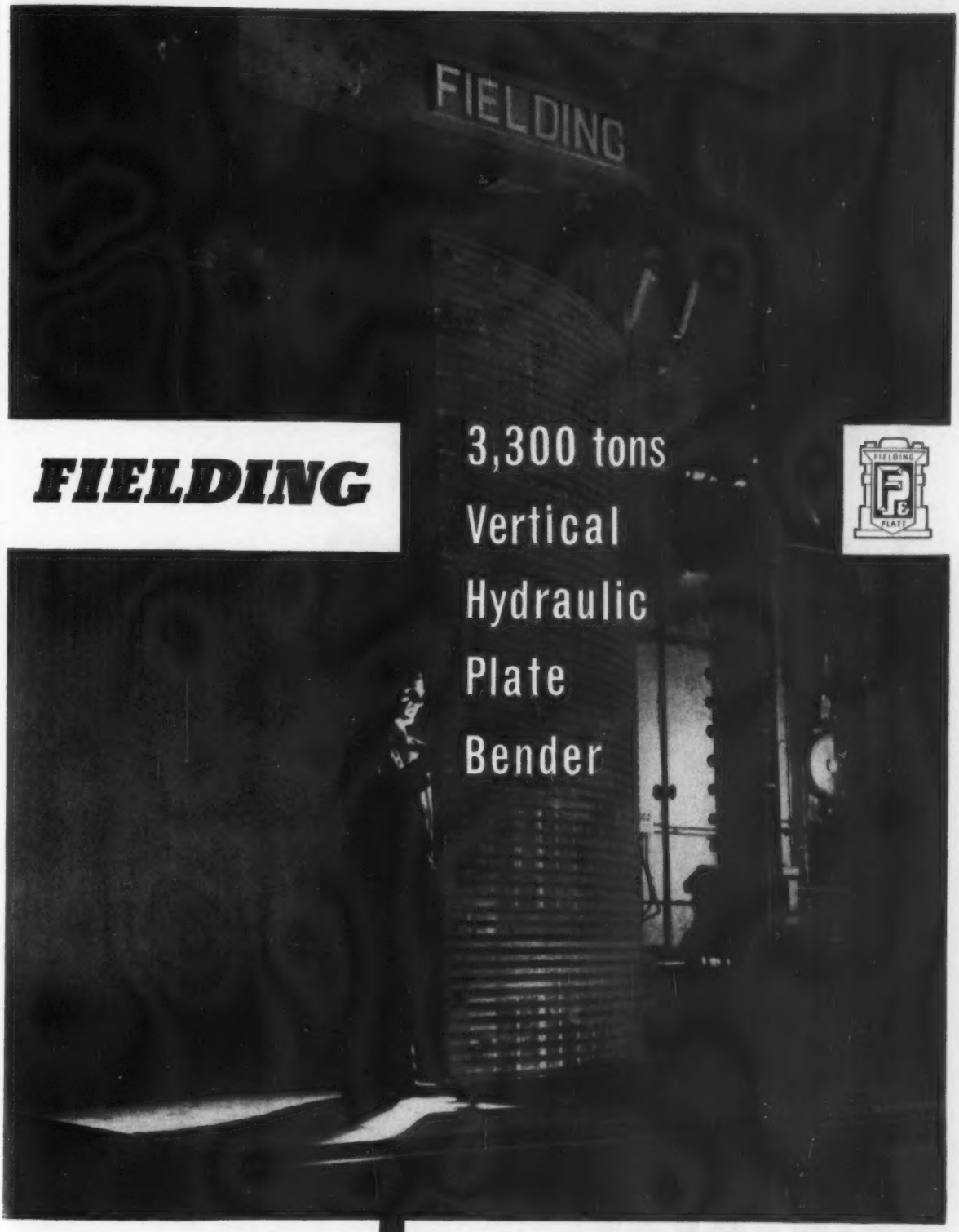

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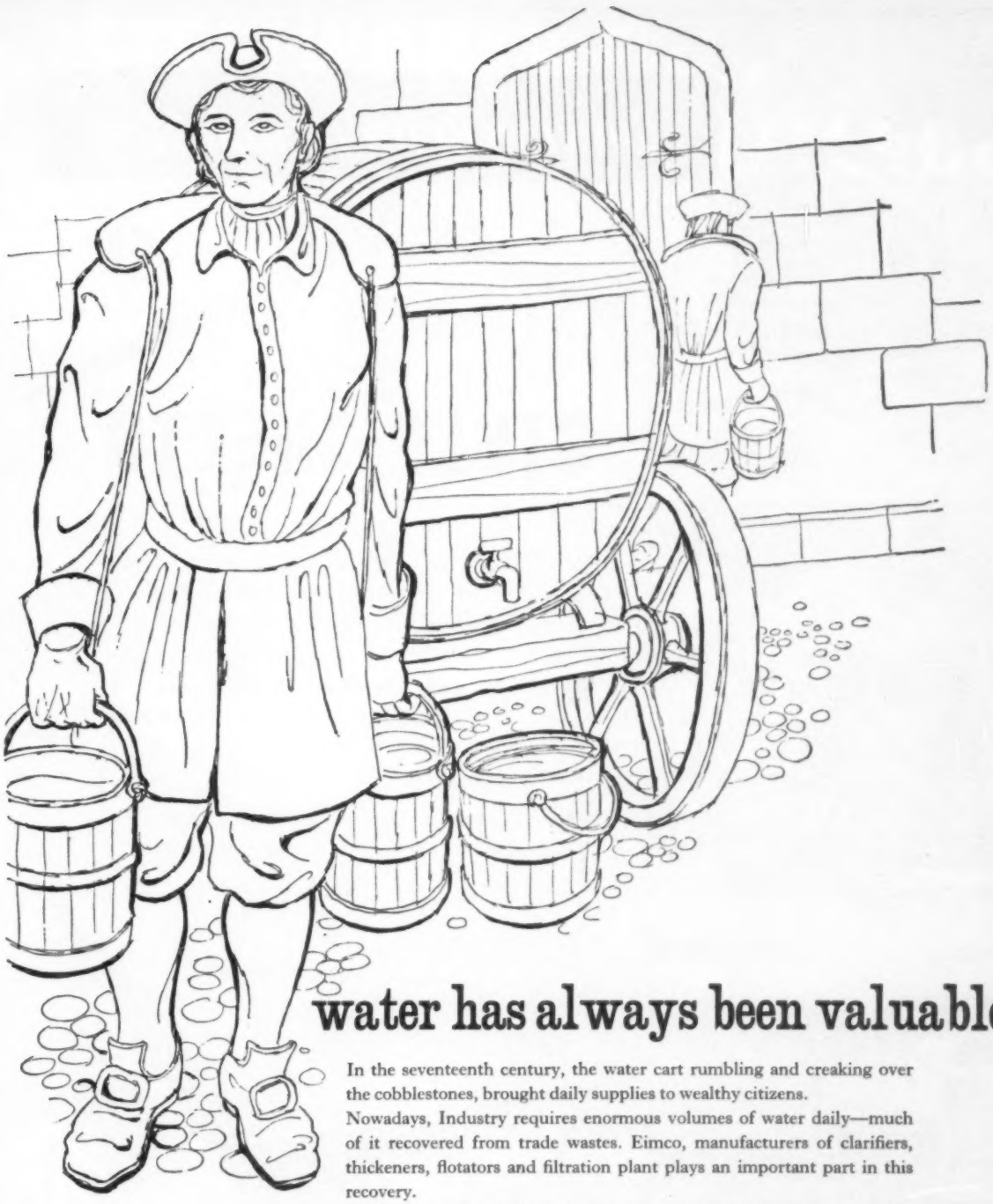

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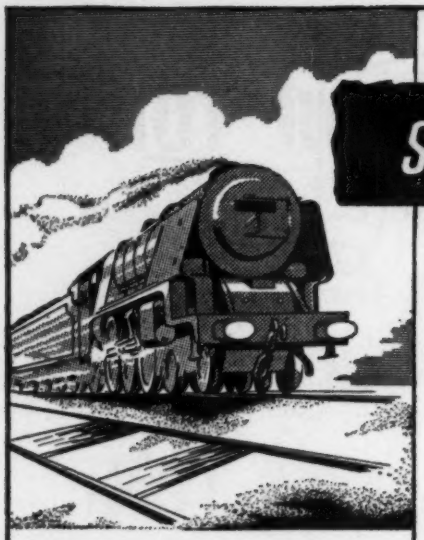

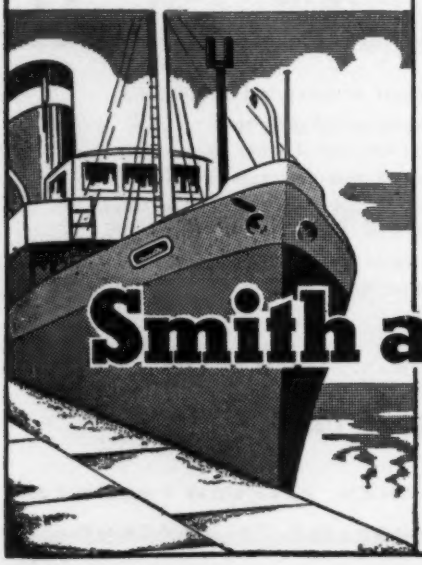

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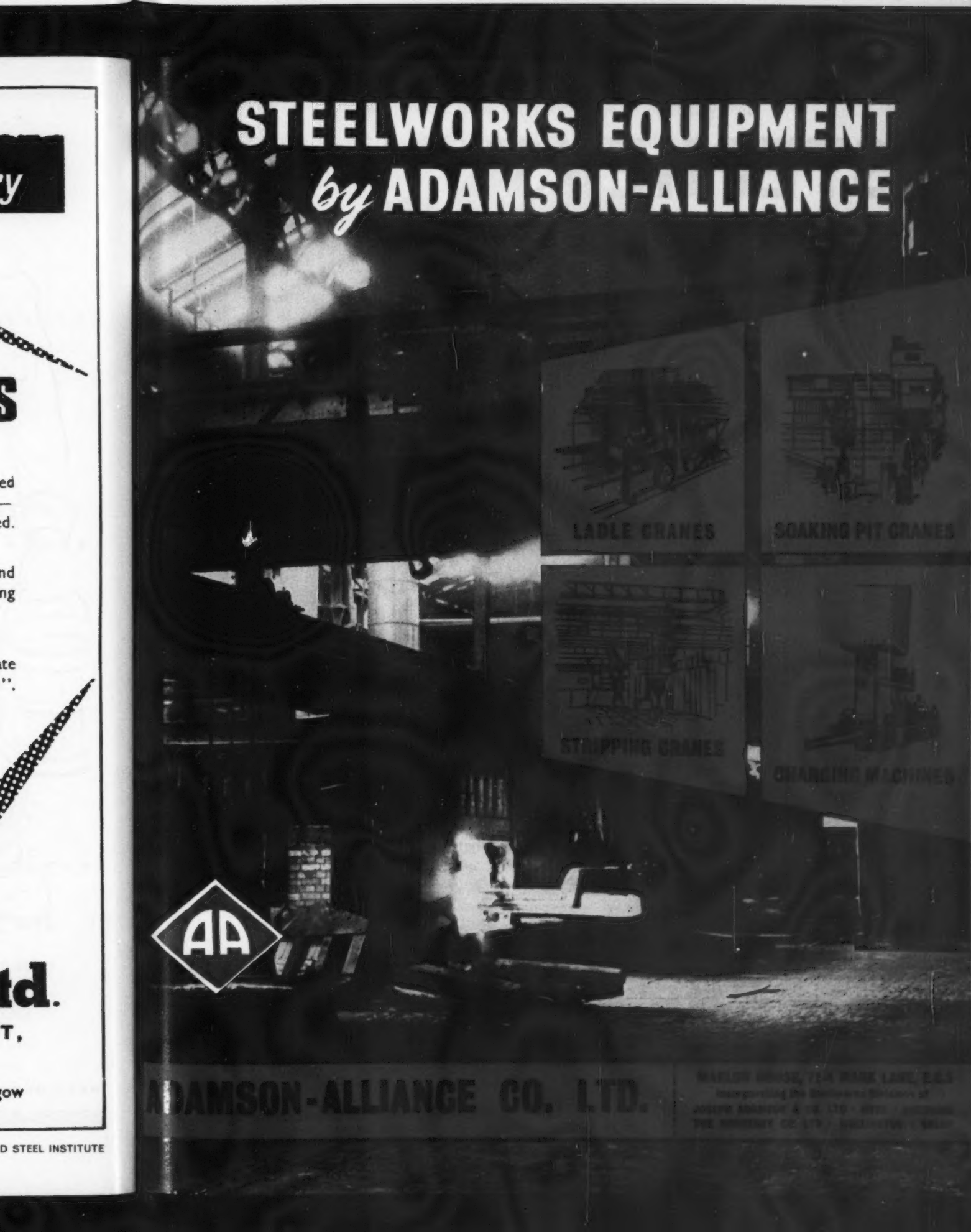
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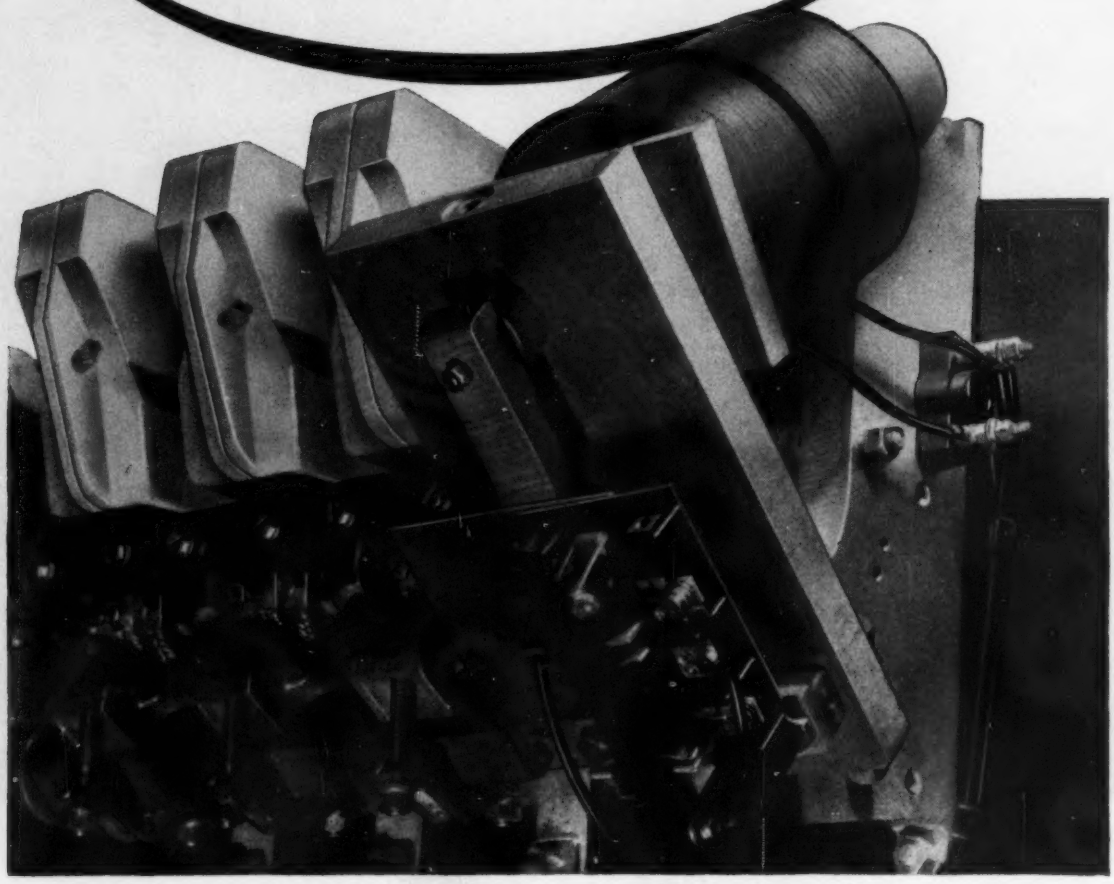

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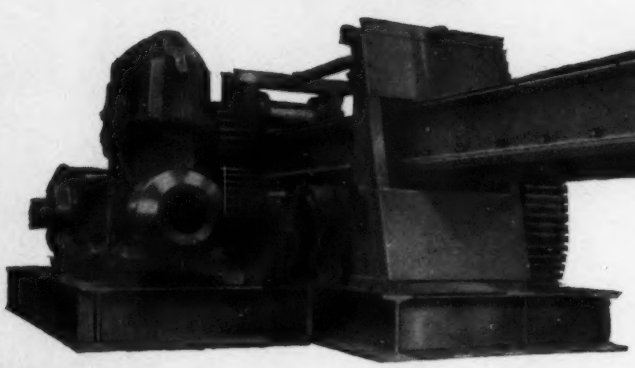

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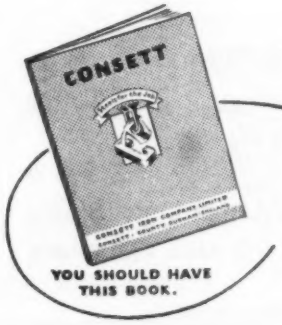

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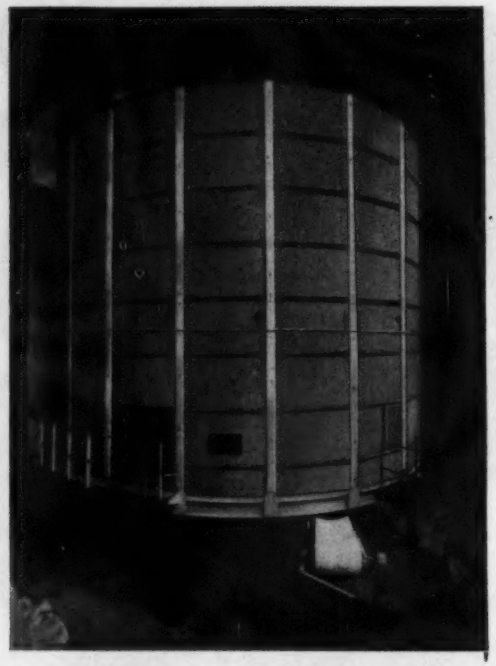

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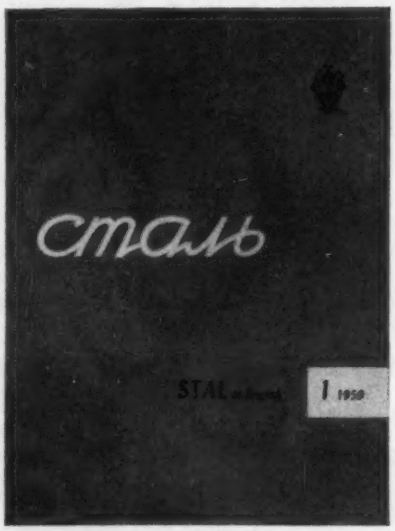

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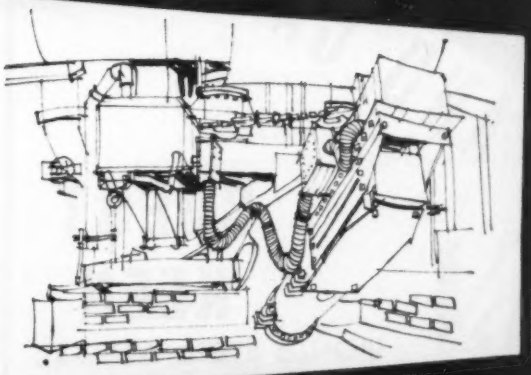

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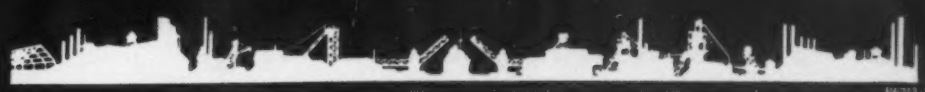

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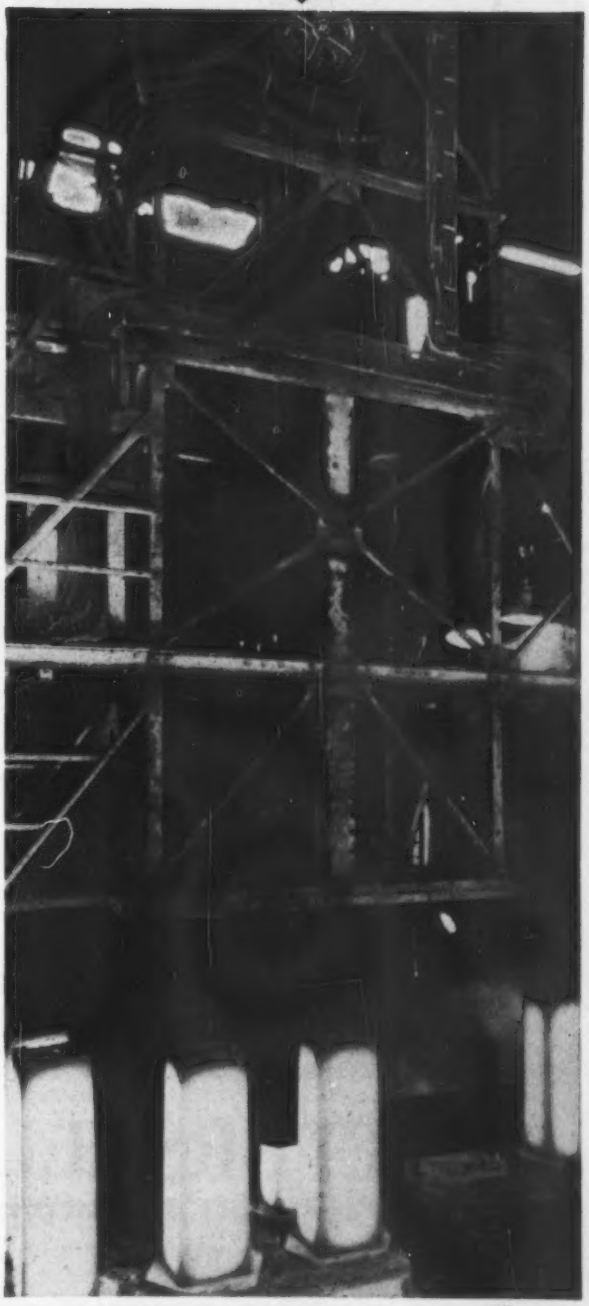

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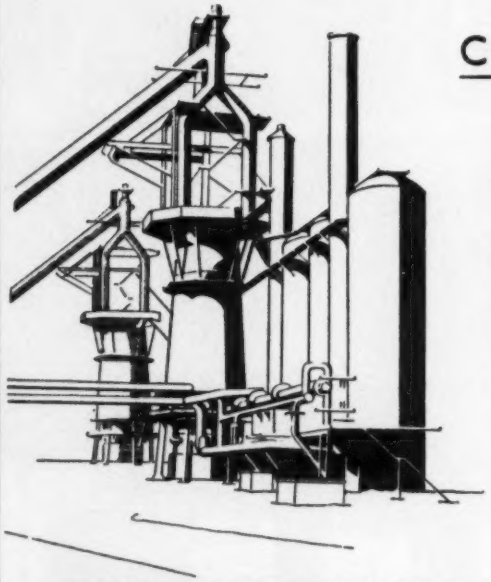

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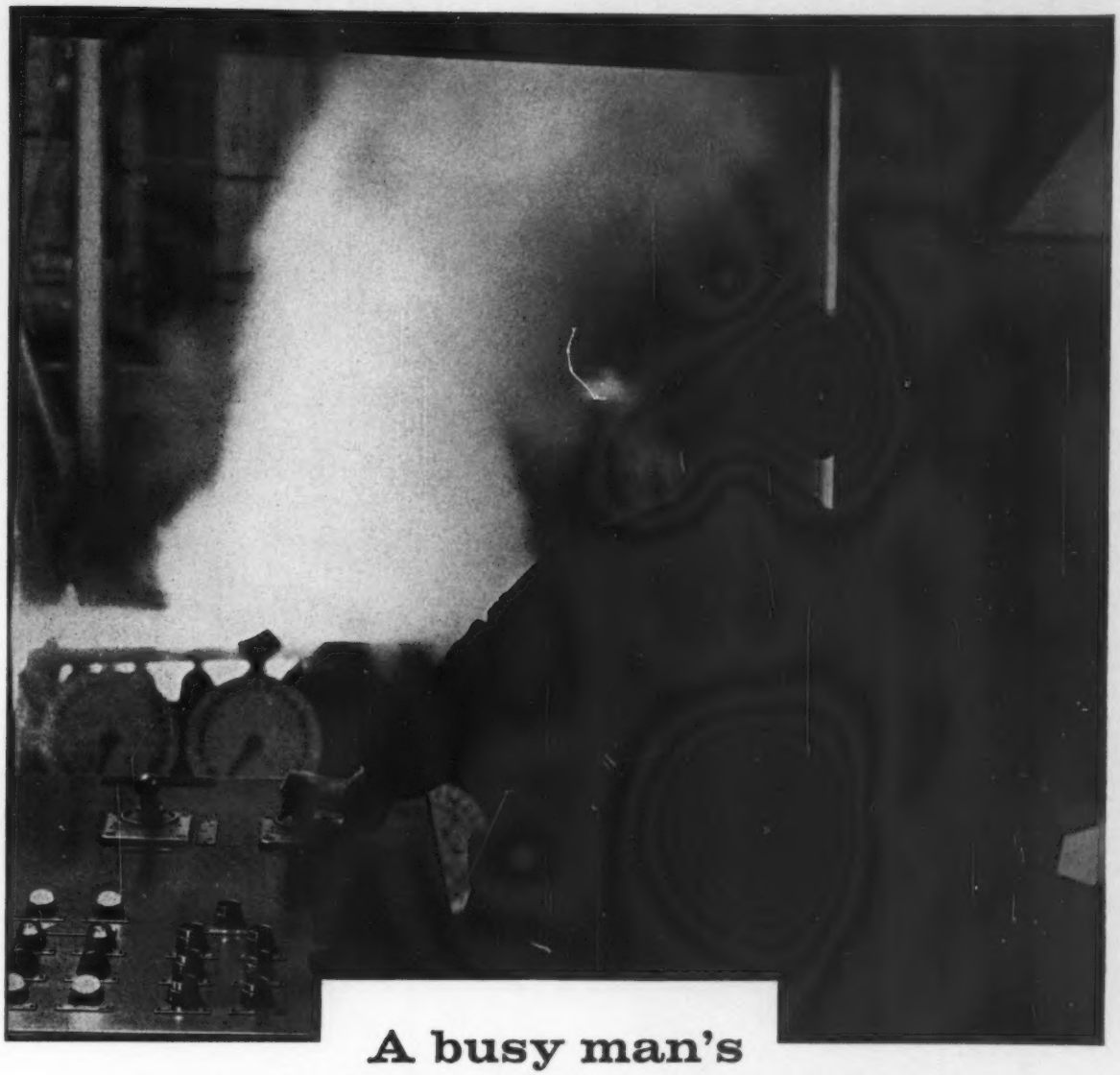

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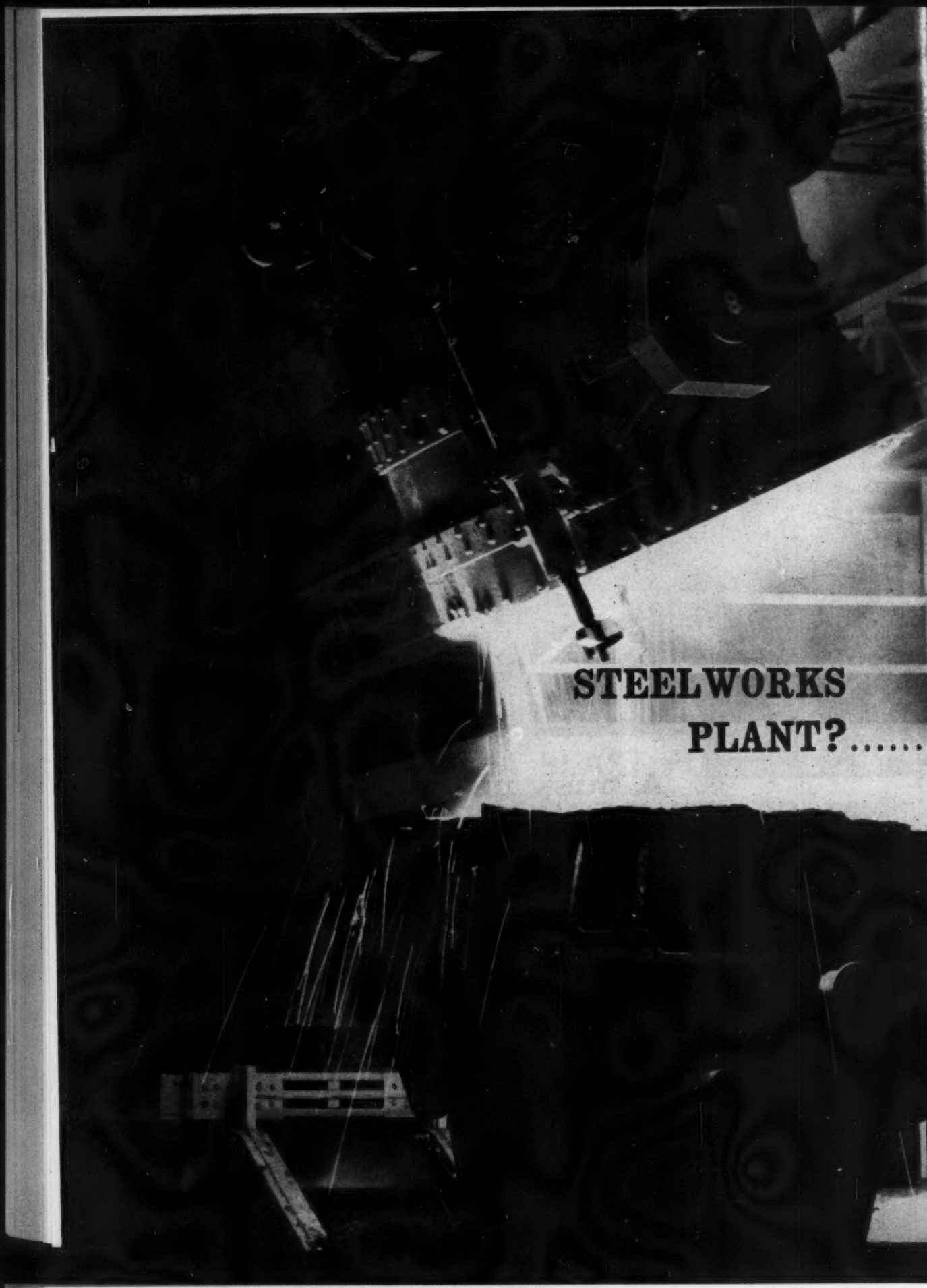
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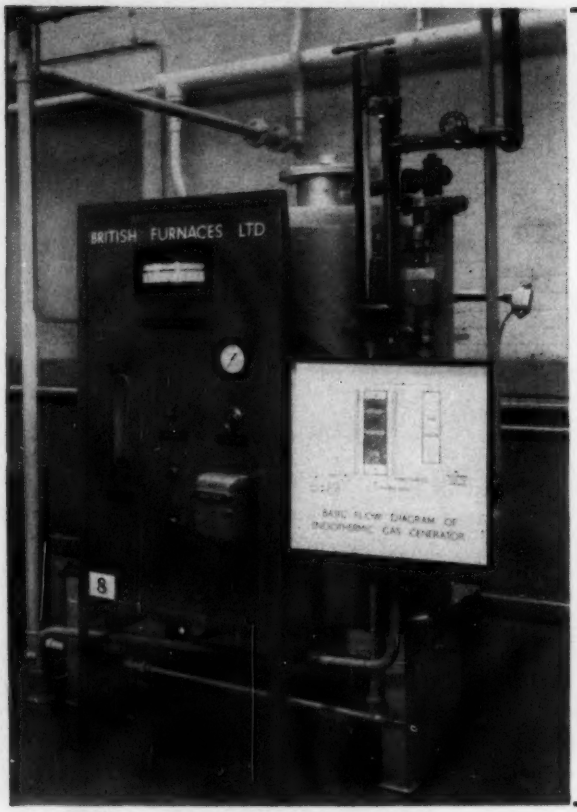

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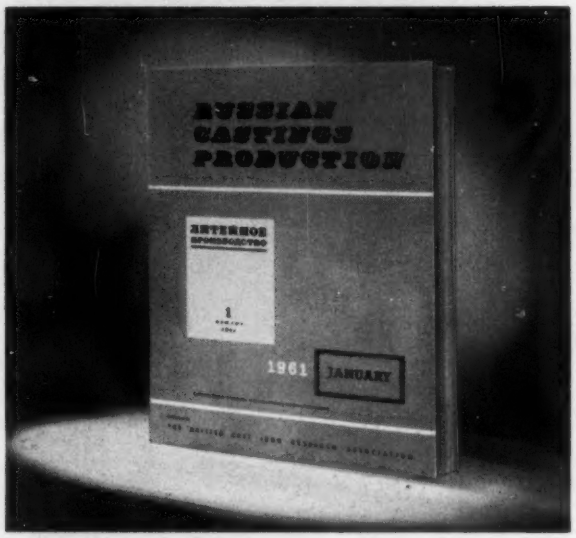

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TITLE .....

COMPANY .....

ADDRESS .....

Index to Advertisers

Continued from page 102

Salem-Brosius (England) Ltd. . . —
Schieldrop & Co. Ltd.. . . . 13
Senior Economisers Ltd. . . . 68
Shaw, John (Salford) Ltd. . . —
Sheepbridge Equipment Ltd. . . —
Shell-Mex & B.P., Ltd. . . 28, 29
Sheppard & Sons Ltd. . . . —
Simon-Carves Ltd. . . . . —
Skefko Ball Bearing Co. Ltd., The . —
Smith, John (Keighley) Ltd. . . 99
Smith & McLean Ltd. . . . 78
Smith, Thomas, & Sons (Rodley) Ltd. 31
Spencer-Bonecourt-Clarkson Ltd. . —
Stanton Ironworks Co. Ltd., The . —
Steel Co. of Wales Ltd., The . . 72
Steel, Peech & Tozer Ltd. . . . 46
Stein & Atkinson Ltd. . . . —
Stein, John G., & Co. Ltd. . . —
Stephens Silica Brick Co. Ltd. . . 80
Stewarts & Lloyds Ltd. . . . —
Stillite Products Ltd. 57
Strachan & Henshaw Ltd. . . —
Sturtevant Engineering Co. Ltd. . 27
Summers, John, & Sons Ltd. . . —
Summerson, Thos., & Sons Ltd. . —

Tattersall & Sons Ltd. 92
Thermal Efficiency Ltd. . . . —
Thermal Syndicate Ltd. . . . —
Thomas (Richard) & Baldwins Ltd.. —
Thompson, John, Ltd. . . . —
Thornton, B., Ltd. 84

Union Carbide Ltd. 43
United Coke & Chemicals Co. Ltd. . 9
United Steel Companies Ltd. 45, 46, 47

Vaughan, Edgar, & Co. Ltd. . . . 89
Visco Engineering Co. Ltd. . . 32

Ward, Thos. W., Ltd. 7
Warner & Co. Ltd. . . . 37
Wellington Tube Works Ltd. . . 2
Wellman Smith Owen Engineering Corporation Ltd., The . . . 1
West Hunwick Silica & Firebrick Co. Ltd. . . . . —
West Instrument Ltd. . . . —
Whipp & Bourne Ltd. . . . —
Whitehead Iron & Steel Co. Ltd. . 76
Wild-Barfield Electric Furnaces Ltd. —
Wincott, G. P., Ltd. 48
Woodall-Duckham Construction Co. Ltd. 52
Workington Iron & Steel Co. . . —
Wragg, Thos., & Sons Ltd. . . —
Wykeham, W. & Co. Ltd. . . . 49

Yorkshire Engine Co. Ltd. 47

sers

. —
. 13
. 68
. —
. —
28, 29
. —
. —
e . —
. 99
. 78
Ltd. 31
. —
. —
. 72
. 46
. —
. —
. 80
. —
. 57
. —
. 27
. —
. —
. 92
. —
. —
d.. —
. —
. 84
. 43
l. . 9
5, 46, 47
. 89
. 32
. 7
. 37
. 2
ing
. 1
Co.
. —
. —
. —
. 76
Ltd. —
. 48
Co.
. 52
. —
. —
. 49
. 47

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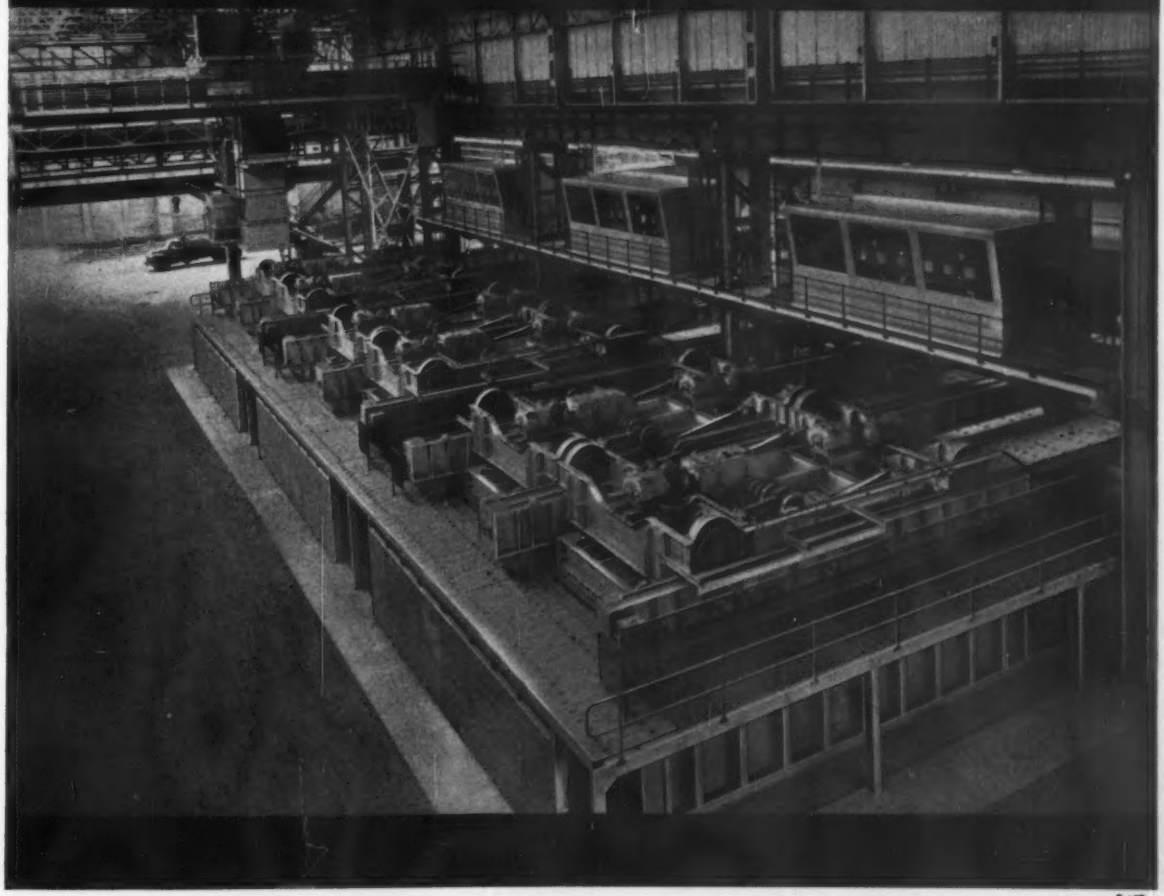


P 157

Index to Advertisers

ACEC . . . . . —
Adamson-Alliance Co. Ltd. . . 79
Adamson, Joseph, and Co. Ltd. . 67
Air Products (Gt. Britain) Ltd. . —
Akers Styckebruk . . . . . —
Allen West & Co. Ltd. . . . . —
Appleby-Frodingham Ltd. . . 45
Armstrong-Whitworth (Metal Industries) Ltd. . . . . —
Arrol, Sir Wm., & Co. Ltd. . . 75
Ashmore, Benson, Pease, & Co. Ltd. Inside Back Cover
Associated Electrical Industries Ltd. 82

B.T.R. Industries Ltd. . . . . —
Barrow Ironworks Ltd. . . . . —
Beardmore, William, & Co. Ltd. . 11
Birlec-Efco (Melting) Ltd . . . 71
Bonnybridge Silica & Fireclay Co. Ltd. . . . . —
Bradley & Foster Ltd. . . . . —
Brightside Foundry & Engineering Co. Ltd., The 83
British Acheson Graphite Ltd. . . —
British Cast Iron Research Assoc. . 100
British Electrical Development Association . . . . . —
British Furnaces, Ltd. 98
British Iron & Steel Federation, The 93
British Paints Ltd. . . . . —
British Railways, Eastern Region . 98
British Rollmakers Corporation Ltd. —
British Timken: Division of the Timken Roller Bearing Co. . . 55
Brookhirst Igranic Ltd. . . . . —
Brown Bayley Steels Ltd. . . . 74
Buell Ltd. 86
Burford, Taylor & Co. Ltd. . . 96
Burn Fireclay Co. Ltd., The . . —
Bushing Co. Ltd., The . . . 44

Carblox Ltd. 97
Clyde Crane & Booth Ltd. . . 17
Colville Group of Companies, The . 15
Consett Iron Co. Ltd. 85
Contactor Switchgear Ltd.. . . 20
Coppee Co. (Gt. Britain) Ltd., The . —
Cowans Sheldon & Co. Ltd. . . —
Craven Bros. (Crane Division) Ltd. . —
Crooks, L. E. . . . . —

D.M.M. Machinery Ltd. 39
Davy & United Engineering Co. Ltd. 54
Deloro Stellite Ltd. 30
Derbyshire Stone Quarries Ltd. . 96
Dewhurst & Partner Ltd. . . . —
Distington Engineering Co. Ltd. . —
Dyson, J. & J. Ltd. Inside Front Cover

Edwards High Vacuum Ltd. . . . 19
Efco Furnaces Ltd. . . . . —
Eimco (Great Britain) Ltd. . . 77
Electroflo Meters Co. Ltd. . . . —
English Electric Co. Ltd., The . . 40
English Steel Castings Corporation Ltd. 81

Fielding & Platt Ltd. 73
Firth, Thomas, & John Brown Ltd. 64
Foster Instrument Co. Ltd. . . 66

G.W.B. Furnaces Ltd. 38
Garringtons Ltd. . . . . —
General Electric Co. Ltd., The . 26, 34
General Refractories Ltd. . . . 3
Gibbons Brothers Ltd. . . . . —
Gibbons (Dudley) Ltd. . . . 8
Great Lakes Carbon International Ltd. 12
Guest, Keen Iron & Steel Works . 88
Guest, Keen & Nettlefolds Ltd. . 60

Hadfields Ltd. . . . . —
Hastie, Bernard, & Co. Ltd. . . 90
Head Wrightson, Iron & Steel Works Engineering, Ltd. 87
Head Wrightson Minerals Engineering, Ltd. 70
Heywood, S. H., & Co. Ltd. . . 5
High Speed Steel Alloys Ltd. . . —
Holmes, W. C. & Co., Ltd. . . 62
Holset Engineering Co. Ltd., The . 36
Honeywell-Controls Ltd. . . . —
Howden, James, & Co. Ltd. . . 59
Huntington, Heberlein & Co. Ltd. . 61

Ilford Limited 41
Imperial Chemical Industries Ltd. . —
International Combustion Products Ltd. 10
International Construction Co. Ltd., The 14, 42
International Nickel Co. (Mond) Ltd. 18

Johnson Matthey & Co. Ltd. . . . 21
Johnson's Rolls Ltd. . . . . —

Kestner Evaporator & Engineering Co. Ltd. 92
Kingscliffe Insulating Products Ltd. —

Lamberton & Co. Ltd. . . . . —
Outside Back Cover
Lanarkshire Steel Co. Ltd., The . —
Lancashire Steel Manufacturing Co. Ltd. 16
Laurence, Scott & Electromotors Ltd. —
Lodge-Cottrell Simon-Carves . . 58
Loewy Engineering Co. Ltd., The . 69
Lysaght's, John, Scunthorpe Works Ltd. 4

Marshall, Thomas, & Co. (Loxley) Ltd. . . . . —
Metallurgical Engineers Ltd. . . —
Midland Silicones Ltd. . . . 91
Mitchell Engineering Ltd. . . . —
Mobil Oil Co. Ltd. 65
Moorwood, John M., Ltd. . . . —
Morgan Refractories Ltd. . . . —
Morgardshammars Mekaniska Verkstads AB 35
Moxey Ltd. . . . . —

National Coal Board, The . . . —
Newell, Ernest, & Co. Ltd. . . —
Newton, Chambers & Co. Ltd. . 94, 95

Oughtibridge Silica Firebrick Co. Ltd. . 50

Pantin, W. & C., Ltd. 24
Park Gate Iron & Steel Co. Ltd. . —
Parsons, C. A., & Co. Ltd. . . 22
Pearson, E. J. & J., Ltd. . . . 33
Pickford Holland & Co. Ltd. . . 63
Plibrico Co. Ltd. 25
Power Petroleum Co. Ltd., The . —
Press, William, & Son Ltd. . . 23
Priest Furnaces Ltd. 101

RN Process Agency . . . . . —
Railko Ltd. . . . . —
Rawlplug Co. Ltd., The . . . —
Reavell-Fahie Ltd. 56
Renold Chains Ltd. . . . . —
Research & Control Instruments Ltd. —
Richardsons Westgarth & Co. Ltd. . —
Robertson, W. H. A. & Co., Ltd. . 6
Rust-Oleum Corporation . . . 90

Continued on page 100

Published at the offices of The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1., and
Printed in Great Britain by Percy Lund, Humphries & Co. Ltd., London and Bradford

. Ltd., The . —
nufacturing Co.
. 16
ctromotors Ltd. —
-Carves . . 58
Co. Ltd., The . 69
unthorpe Works
. 4

Co. (Loxley)
. . . . . —
ers Ltd. . . —
d. . . . 91
Ltd. . . . —
. . . . 65
Ltd. . . . —
Ltd. . . . —
lekaniska Verk-
. 35
. . . . . —

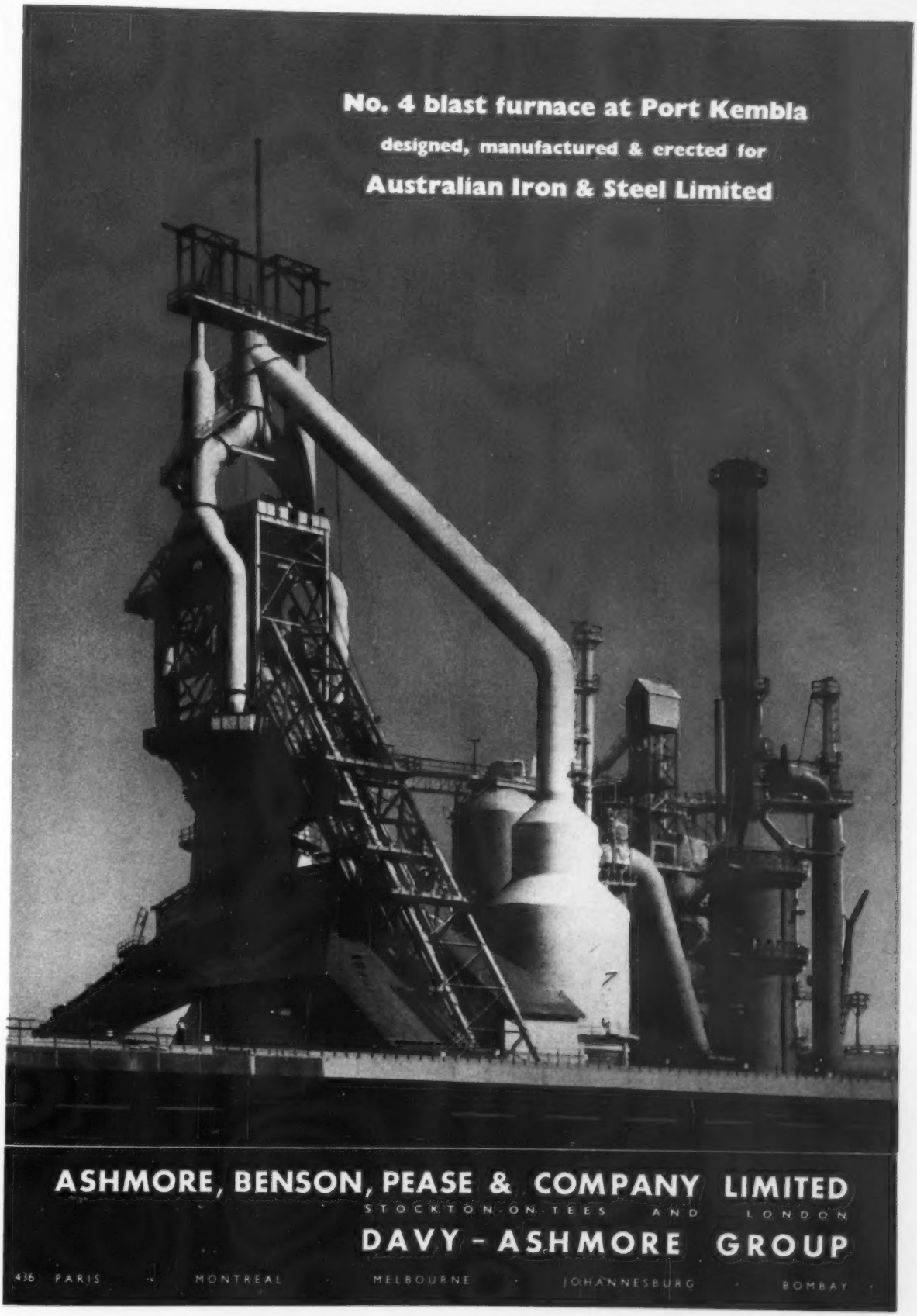
e . . . . —
. Ltd. . . —
Co. Ltd. . 94, 95

brick Co. Ltd. . 50

. 24
eel Co. Ltd. . —
. Ltd. . . 22
Ltd. . . . 33
Co. Ltd. . . 63
. 25
. Ltd., The . —
n Ltd. . . 23
. 101

. . . . . —
. . . . . —
The . . . . —
. 56
. . . . . —
Instruments Ltd. —
rth & Co. Ltd. . —
. & Co., Ltd. . 6
tion . . . 90

Continued on page 100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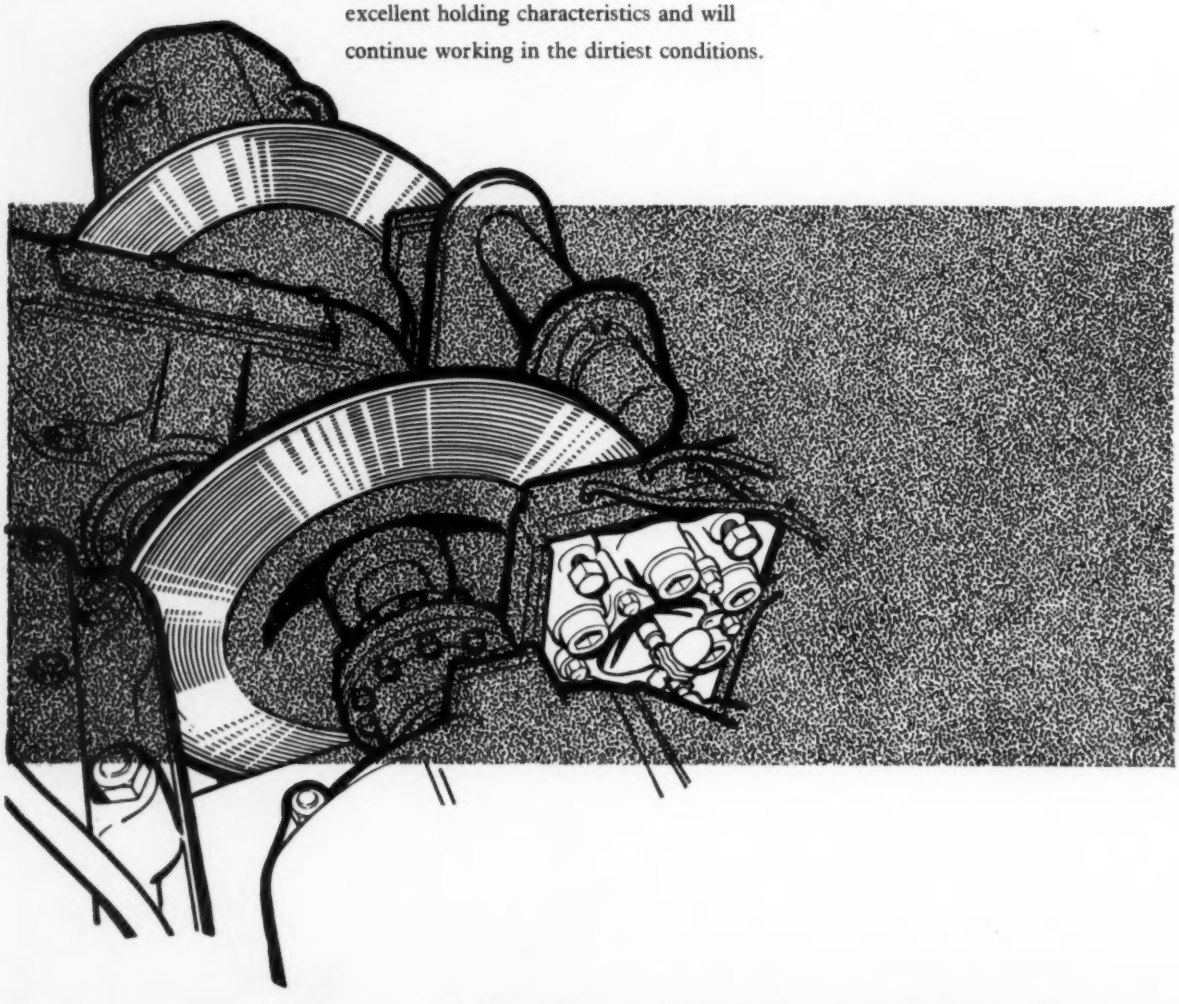

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